

MCDONNELL DOUGLAS TECHNICAL SERVICES COMPANY, INC.

HOUSTON ASTRONAUTICS DIVISION

16015 El Camino Real, Suite 220, Houston, Texas 77058

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To: NASA/Lyndon B. Johnson Space Center
Attention: M. V. Jenkins, FM4
2101 NASA Road 1
Houston, Texas 77058

Enclosure: (1) Design Note No. 1.4-4-33, "Abort Region
Determinator (ARD) Module Feasibility
Report"

1. The enclosure presents a feasibility analysis of the OFT Mission Control Center (MCC) software formulation requirements for the Abort Region Determinator processor. This analysis demonstrates that the baselined ARD module meets all design objectives for MCC OFT launch/abort support.

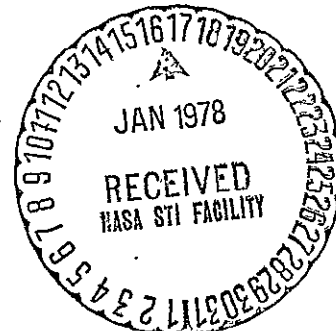
Very truly yours,

W. E. Hayes

W. E. Hayes
Project Manager
Mission Planning, Mission Analysis
and Software Formulation

WEH:csc

EC: R. L. Berry/FM8
A. Bordano/FM7
R. O. Nobles/FM17
Distribution Operations (3)/JM86
J. D. Yencharis/FM4



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MCDONNELL DOUGLAS TECHNICAL SERVICES CO.
HOUSTON ASTRONAUTICS DIVISION

SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT

DESIGN NOTE. NO. 1.4-4-33

ABORT REGION DETERMINATOR (ARD) MODULE FEASIBILITY REPORT

MISSION PLANNING, MISSION ANALYSIS AND SOFTWARE FORMULATION

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This Design Note is Submitted to NASA Under Task Order
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PREPARED BY: Billy G. Draeger
B. G. Draeger
Engineer
Dept. E904, Ext. 243

PREPARED BY: J. A. Joyner
J. A. Joyner
Task Manager - ARD
Dept. E904, Ext. 243

CONTRIBUTION BY: Glen D. Venables
G. D. Venables
Senior Engineer
Dept. E904, Ext. 243

APPROVED BY: L. C. Winans
L. C. Winans
Integration Manager -
Intact Aborts
Dept. E904, Ext. 243

APPROVED BY: W. W. Hinton Jr.
W. W. Hinton
Technical Manager-Return
and Abort Analysis
Dept. E914, Ext. 240

APPROVED BY: W. E. Hayes
W. E. Hayes
Project Manager
Mission Planning, Mission
Analysis and Software
Formulation
Dept. E914, Ext. 266

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ACRONYMS AND SYMBOLS

<u>Acronym or Symbol</u>	<u>Definition</u>
AM	Actual Mode
AOA	Abort Once Around
ARD	Abort Region Determinator
ATO	Abort to Orbit
BRR	B Rid Review Board
CR	Change Request
CRT	Cathode Ray Tube
ET	External Tank
FAB	Flight Analysis Branch
FOD	Flight Operations Directorate
γ	Earth-Relative Flight Path Angle
HM	Hypothetical Mode
MC	Mission Completion
MCC	Mission Control Center
MECO	Main Engine Cutoff
MED	Manual Entry Device
MDTSCO	McDonnell Douglas Technical Services Company
MPAD	Mission Planning and Analysis Division
MPS	Main Propulsion System
NOM	Nominal
OFT	Orbiter Flight Test
PBI	Push Button Indicator
PET	Phase Elapsed Time From Liftoff

ACRONYMS AND SYMBOLS

<u>Acronym or Symbol</u>	<u>Definition</u>
RTLS	Return to Launch Site
SSME	Space Shuttle Main Engine
SSR	Staff Support Room
SVDS	Space Vehicle Dynamic Simulation
TLM	Telemetry
VE	Earth Relative Velocity Magnitude
$\overline{VE}$	Earth Relative Velocity Vector
VI	Inertial Velocity Magnitude
$\overline{VI}$	Inertial Velocity Vector
RI	Inertial Radius Magnitude
$\overline{RI}$	Inertial Radius Vector
W	Total Vehicle Weight

1.0 SUMMARY

A software module feasibility study has been completed for the Mission Control Center (MCC) Abort Region Determinator (ARD) processor.

This study addresses the feasibility of the basic ARD module function in support of single-failure launch aborts. The analysis here is generally restricted to the ARD Module independent of other MCC processors and interfaces. A complete study would also encompass ARD module function in an integrated MCC environment for both single-failure and multiple-failure aborts. Such an integrated scheme feasibility study will be conducted as a follow-on to this analysis.

This study provides a detailed performance evaluation of the present ARD module design in support of OFT-1 ascent and OFT-1 intact launch aborts. The evaluation method used is to compare ARD results against results obtained using the full-up Space Vehicle Dynamic Simulations (SVDS) program under the same conditions. Results are presented for each of the three major ARD math models (the Ascent Numerical Integrator, the Mass Model, and the Second Stage Predictor) as well as the total ARD module. These results demonstrate that the baselined ARD module meets all design objectives for MCC OFT launch/abort support.

In addition, this study does explore one aspect of ARD module function in an integrated MCC environment. The study includes an analysis of the ARD/Special-MPS-processor MCC interface and the adequacy of this interface for off-nominal conditions. While this is, strictly speaking, an integrated scheme feasibility consideration, this question is judged to be of fundamental importance and is included in this report.

As an additional feature, this study also addresses the adequacy of baselined ARD MCC displays. In MCC application the results of ARD processing will be used to update a digital CRT display on the flight dynamics consoles at six-second intervals. To facilitate evaluation of the ARD digital display design, ARD results are presented in this study exactly as they will appear in the MCC for nominal ascent and four launch abort scenarios. These results provide a good indication of the capabilities and limitations of the digital display.

2.0 INTRODUCTION

The Flight Analysis Branch (FAB) of the Mission Planning and Analysis Division (MPAD) at Johnson Space Center (JSC) is responsible for defining software formulation requirements for the Mission Control Center launch/abort processors that will be used to support Shuttle ascent operations. MPAD is also responsible for developing mission techniques and procedures required in the application of these processors by mission controllers in the MCC.

The Abort Region Determinator is the launch/abort monitor that will be used in the Mission Control Center to support Shuttle ascent operations. McDonnell Douglas Technical Services Company (MDTSCO) is charged with the MPAD development responsibilities for this MCC processor. This task is part of the Space Shuttle Engineering Operations Support Contract and is being conducted under the direction of Morris V. Jenkins, MPAD FAB Branch Chief.

Based on the level A requirements of reference 1 and the Flight Operations Directorate (FOD) statement of requirements (reference 2), initial formulation requirements for the ARD were developed and baselined in references 3 and 4. These requirements have been revised to date by two formal requirements change documents as a result of bench program development and ARD feasibility studies (references 5 and 6). First generic techniques and procedures for ARD application have been provided in reference 7. Currently, ARD task emphasis is shifting from the software requirements definition phase to review, testing and verification of the software for the first MCC build. A detailed test plan (reference 8) has been

published that defines a procedure for verification of MCC software using the ARD bench program developed by MDTSCO and Lockheed Software Development Branch personnel. A trajectory test data base (references 9, 10, and 11) has also been established for use in this MCC software verification effort. Detailed MCC software implementation plans are presently under review by MDTSCO as part of the ARD Critical Design Review.

This study utilizes an ARD bench program as developed to 1 October 1977 (October 1977 ARD Milestone). This milestone includes all ARD bench-program-development change request (CR) items approved to 1 October 1977 by the level B requirements review board (BRR) (reference 12). The milestone also include a baselined third-order analytic predictor improvement CR item approved by the BRR on 17 October 1977.

The study also utilizes Milestone 3.7 of the SVDS program presently under development by Software Development Branch. The OFT-1 no-roll trajectories generated with this program are generally consistent with the reference flight profile (RFP) document of reference 13.

3.0 ARD MODULE FEASIBILITY-APPROACH AND ANALYSIS

ARD detailed formulation requirements have been implemented in a bench program simulation of ARD MCC software. In order to verify the feasibility of this formulation, the ARD bench program was run in simulated support of the following launch and launch/abort trajectories:

- 1) Nominal OFT-1 ascent from liftoff to MECO for mean April winds;
- 2) Nominal no-wind OFT-1 liftoff to MECO ascent;
- 3) AOA abort of the mean-wind OFT-1 ascent with center SSME failure at 213 seconds and abort enactment at 233 seconds after liftoff;
- 4) ATO abort of the no-wind OFT-1 ascent with center SSME out at 245 and abort enactment at 265 seconds after liftoff;
- 5) RTLS abort of the mean-wind OFT-1 ascent with center SSME failure at liftoff and abort enactment at 126 seconds after liftoff;
- 6) Mission completion of the mean-wind OFT-1 ascent following partial loss of center SSME thrust at 66 seconds after liftoff.

The approach in each of these simulations was to run the ARD bench program on a simulated telemetry (TLM) state vector file generated with the SVDS program. ARD/flight controller interfaces were simulated to approximate ARD MED and PBI control action that will be experienced in the MCC. For each trajectory, ARD results were then compared with results from the SVDS. This comparison provides for each case a detailed measure of ARD accuracy and ARD module support feasibility.

This section presents the results of the feasibility analysis for each of these trajectories. In each case ARD support is presented graphically as well as in terms of the flight controller's digital

display. The ARD-support graphs demonstrate clearly the trends and characteristics of the ARD for the various support situations. Such graphs have been proposed by MDTSCO for MPAD flight dynamics SRR support and are currently being considered for MCC display. The digital displays of the figures that follow provide ARD results exactly as they will appear on the MCC consoles during ascent (see Reference 15). This display is presently the primary ARD flight controller tool and gives the granularity and ARD control parameters required for ARD support. A close scrutiny of the figures of this section, however, confirms that the digital display does not readily identify some important trends and characteristics of ARD support. (Note that displays are provided at selected points only. In the MCC, ARD displays will be updated at the end of each 6-second interval throughout ascent. Additional displays are available on request.) Detailed accuracy study results are also presented for each of the three major ARD math models.

The developmental status of the computer simulations used must be considered in reviewing the results of this section. In the MCC, margins for other abort modes will not be displayed once an abort mode PBI has been selected. The ARD bench program does not simulate this function and margins for the other modes are displayed in this section even after mode selection. These margins should be disregarded. There is also an unresolved problem with the bench program display of the RCS DELV (see Reference 15). This display slot should also be disregarded. These items are due to the immaturity of the bench program and do not reflect on the ARD formulation.

Note also that the SVDS program used has no model of the MECO standard-SSME shutdown procedure. This means that MECO results obtained with this program are somewhat optimistic. Real MECO velocity margins will be up to 5 feet per second less than those presented here. And actual MECO times will be 1 to 5 seconds later than those of this section. This inaccuracy does not compromise the validity of the ARD/SVDS comparison. In fact, the ideal MECO times of this program allow a direct comparison of ARD-predicted and SVDS-actual times that could not otherwise be made.

3.1 ARD Nominal Ascent Support

ARD nominal ascent support feasibility is assessed in this section for both mean April winds and a no-wind OFT-1 ascent trajectory. The mean-wind trajectory is representative of actual OFT-1 ARD support. The no-wind trajectory is required for detailed ARD math model accuracy analysis and provides a measure of the effect of winds of the day on ARD margin predictions.

Figures 1.1 and 1.2 provide a complete graphical summary of ARD support for mean-wind OFT-1 ascent. This information is also presented in digital display format in figure 1.3. Since this trajectory is consistent with reference 14, basic ARD feasibility for this case is assessed by comparing these results with the data of reference 14. Table 1 provides this comparison and illustrates the capability of the ARD to define abort boundaries for OFT-1. Note in all cases the good agreement of ARD bench program results and the independently-derived SVDS results of reference 14. Also note the comparison of ARD predicted nominal margins versus the SVDS results.

There are several important aspects of the figures 1.1-1.3 that should be pointed out:

- 1) the effect of using a wind-biased first-stage body axis command table in the no-wind ARD first-stage integrator is indicated by the difference in the AM margins for liftoff versus the margins at SRB staging (126 seconds after liftoff. Also refer to Table 5.1);
- 2) AM margins for nominal, ATO and AOA are identical since abort

and nominal targets are the same and since no pre-MECO OMS/RCS burns are scheduled in 3-SSME aborts for OFT-1;

- 3) The effect of the OFT-1 throttle bucket is apparent in the HM margins between 35 and 65 seconds after liftoff;
- 4) The mission completion design of the ATO pre-MECO OMS/RCS burns is reflected in the ATO margins after 250 seconds.

These trends are evident in all of the figures of the appendix.

Figures 1.4-1.6 summarize ARD support for no-wind OFT-1. Since the ARD is predicated on a no-wind ascent model, this trajectory affords the best opportunity for detailed comparison of the ARD against SVDS from liftoff to MECO. Table 2 presents such a comparison for a wide range of points selected from figures 1.4-1.6. Tables 3-5 provide a similar assesement of the performance of the major ARD component math models vs. the corresponding models of SVDS.

A comparison of the ARD results for the mean-wind ascent versus the no-wind ascent identifies one area of inaccuracy in the present ARD implementation. Present plans are now to use the onboard wind-biased first-stage guidance commands in the ARD for OFT support. Figure 1.1 and Table 1 clearly demonstrate the inaccuracy associated with use of wind biased commands in the no-wind ARD. Figure 1.4 illustrates the improvement possible if no-wind commands were used instead.

3.2 ARD Mission Completion Support

In addition to its primary task of providing abort region predictions in abort situations, the ARD is first required to identify the situations in which an abort is required. This section addresses the capability of the present baseline to perform this task.

Figures 2.1-2.3 summarize ARD support for an SSME-partial-loss-of-thrust failure occurring during the throttle-up portion of the OFT-1 throttle bucket. In this simulation, SSME-1 locked at 76% throttle 66 seconds after liftoff and remained at that level throughout ascent to MECO. All other aspects of this trajectory are identical to the mean-wind nominal ascent of section 3.1. Note that three applications of the ET fuel adjustment MED were required here to match ARD mass track results with those of the spline interpolators of SVDS. Figure 2.1 illustrates the affect of these MED's.

Table 6 summarizes ARD performance for this scenario. Immediately following the failure, the first question facing the flight team is whether an abort situation exists. For this situation the ARD margins of the figures indicate that it does not (i.e., no abort action is required). SVDS results in table 6 confirm the validity of the ARD prediction.

Figures 2.1-2.3 illustrate the capability of the ARD to predict significant shifts in the abort regions. By comparing the HM 2-SSME boundaries of these figures with those of figures 1.1-1.3 (see table 6) the effect of the SSME-lock failure on 2-SSME abort posture is apparent. Note that while the downrange abort boundaries have been

significantly perturbed, the region of RTLS capability remains relatively unaffected. ARD capability to predict this shift in the mode boundaries is very important here, since for hydraulic-lock-induced failures it is likely that the sick engine will fail entirely 1-2 minutes after the partial-loss-of-thrust failure.

3.3 ARD Abort-to-Orbit (ATO) Abort Support

This section details ARD capability to predict valid ATO abort regions and support a selected ATO abort. Figures 3.1-3.3 summarize ARD support for a typical ATO OFT-1 launch abort situation. In this case complete loss of center SSME thrust was experienced 245 seconds into a no-wind OFT-1 ascent. Following a 20 second abort decision delay, an ATO abort was enacted and completed. The ARD digital displays in Figure 3.3 are provided from the time of the failure. Displays prior to this time are identical to those of Figure 1.6.

Table 7 summarizes ARD performance in support of this launch abort. The agreement of ARD ATO abort predictions and SVDS results here confirms ARD feasibility for this case.

There are several features of figure 3.1 that should be observed:

- 1) Margins for this case are identical to the no-wind ascent margins of section 3.1 up to the time of engine failure;
- 2) ARD response to the center-SSME-out PBI is apparent in the AM at 245 seconds;
- 3) ARD auto-safing is confirmed on figure 3.3 at 245 seconds;
- 4) AM and HM reconfiguration following engine-out PBI is confirmed since AM & HM margins are identical following the failure;
- 5) The validity of HM application is confirmed by comparing HM margins just prior to the failure to the final result.

These effects are also evidenced in the AOA and RTLS results that follow.

3.4 ARD Abort Once Around (AOA) Abort Support

ARD module feasibility for AOA abort region definition and AOA abort support is assessed in this section. The failure simulated here is complete loss of center SSME thrust at 213 seconds after liftoff. Following a 20-second delay, an AOA abort is enacted and completed. Figures 4.1-4.3 provide a summary of ARD support for this case. Table 8 summarizes ARD performance in support of this abort. Note that digital display information in Figure 4.3 starts at time of engine failure. Displays prior to this time are identical to those of Figure 1.3.

3.5 ARD Return to Launch Site RTLS Abort Support

The ARD was run in simulated support of a worst-case-type RTLS abort. The trajectory simulated was for complete loss of center SSME thrust at liftoff with RTLS selected at the beginning of second stage ascent. Figures 5.1-5.3 detail ARD support for this case. Note that this simulation begins at SRB staging. Table 9 summarizes ARD performance for this support.

There are several unique features of figure 5.1 that should be observed for this case:

- 1) Start of RTLS pitcharound is clearly reflected in both the AM and HM at 411 seconds;
- 2) The difference in AM and HM margins reflects the difference in flyback capability with present throttles (96%) versus ultimate capability with maximum performance (109%);
- 3) The conservative onboard and ground RTLS turnaround extrapolation algorithm as evidenced in the HM between 411 and 423 seconds;
- (4) The effect of the SSME-lock MED adjusting throttles from 100% to 95% is apparent in AM between 417 and 423 seconds.

These will be characteristic of ARD support of all RTLS aborts.

3) ARD/Special-Main Propulsion System (MPS)-Processor Interface Feasibility

The ARD functions based on the mass properties computations (i.e., total weight, MPS fuel remaining, OMS/RCS fuel remaining) of the ARD nominal mass track. The mass track assumes nominal main-engine performance based on input throttle settings. There are no provisions in the mass track for off-nominal performance or engine-to-engine performance dispersions for a given throttle setting. Moreover, with the present ARD control design, the flight team has no way of adjusting the mass track for the small throttle fluctuations about the nominal value that are considered likely to occur.

To account for these off-nominal performance conditions, a comparison interface has been established between the ARD and a special MPS processor. This processor computes mass properties based on detailed propulsion system status information (chamber pressures, temperatures, flow rates, etc.) downlinked via telemetry and is intended to provide an accurate comparison base for other MCC processors. Detailed requirements for this processor are given in reference 16. The established interface presently provides for the flight controller to maintain an accurate ARD mass track by periodic MED adjustments based on the output of this MPS processor.

A study was undertaken to evaluate the validity of this MCC interface. Based on the anticipated accuracy of the special MPS processor computations (reference 17) a set of worst-case special MPS processor errors were generated for OFT-1. These errors are summarized in figure 6.1. ARD support was then simulated for no-wind OFT-1 ascent using these errors as MPS-fuel-remaining-adjustment MEDS to simulate the

APD/special-MPS-processor interface. Figure 6.2 and 6.3 summarize ARD support for this case. By comparing the results of figures 6.2 and 6.3 to the nominal results of figures 1.4 and 1.5, worst-case ARD errors resulting from the worst-case special MPS processor errors were derived. (Note that this study was conducted for second stage ascent only. The first stage was judged to be very insensitive to weight errors. The results obtained confirm this assessment.)

Figure 6.4 presents these results for both positive and negative worst-case errors. From this figure it is apparent that while the ARD is very insensitive to special MPS processor errors early in ascent, it becomes progressively more sensitive as ascent progresses. In view of the magnitude of the OFT-1 FPR (roughly 260 fps), in fact, the errors near MECO must be regarded as totally unacceptable. (Note in figure 6.4 the error-damping effect of the ARD constant acceleration mass track after 460 seconds.) These errors are particularly serious in view of current proposals for ARD to support intact contingency (i.e., multiple SSME-out) aborts near MECO.

There are a number of alternative solutions to this difficulty. In order to provide an indication of the improvement possible, comparable worst-case mass properties errors were assessed for one of these. The alternative investigated is the simple sensed-thrust-velocity algorithm presented in reference 18. This algorithm is only valid for exoatmospheric flight. Therefore, for this evaluation it was assumed that the present special MPS processor was used until SRB staging. The sensed-thrust-velocity algorithm was then used to provide comparison weights from staging to MECO. (Note that the

input weight error to the algorithm is in fact, a conservative 1000 pounds worse than the observed MPS processor error.). Figure 6.5 presents worst-case weight errors using this algorithm versus those of the present special MPS processor. Now the sensed-acceleration algorithm errors of this figure are somewhat over-optimistic. There is a 3800 pound uncertainty in the dry weight of the vehicle that defines a lower limit on achievable weight uncertainties. Also there may be, depending on the implementation, errors associated with the sensed-velocity input to the algorithm in the MCC, but even with these considerations, the errors of Figure 6.5 offer a significant improvement over the present scheme. Based on these errors, it is judged that there are alternative comparison bases that could reduce attendant ARD margin uncertainties to well within FPR level.

5.0 Conclusions and Recommendations

This paper demonstrates the basic feasibility of the baselined ARD formulation in MCC support of shuttle OFT ascents and intact launch aborts. ARD OFT-1 design characteristics identified in this analysis are summarized in Table 10. The only significant module discrepancy identified by this analysis is the useage of wind-biased first stage guidance commands in the no-wind first stage ARD model. While the present baseline is in full compliance with Level A and B ARD design requirements, these studies indicate that the wind-biased command set may not be the best one for ARD application. It appears that a no-wind profile might provide better ARD first stage predictions. There is presently, however, no source of such a profile, since MPAD ascent design is only being conducted for ascents with winds. Moreover, ARD inaccuracies due to this effect are only significant for the first one to one-and-one-half minutes of ascent. It is recommended that this issue be addressed by MPAD and an MPAD position determined at the earliest possible date.

The figures of this document illustrate the limitations of the present ARD digital display in readily identifying important ARD characteristics and trends. The figures also demonstrate the utility of ARD margin history plots in readily identifying such trends. While these plots are of interest to the flight team as a whole, they are judged to be essential for MPAD flight dynamics SSR support of ARD applications. Margin history plots have been proposed but not yet baselined for

implementation in the MCC common display system. It is recommended that MPAD press for baselining of these MCC plots at the earliest opportunity.

This document also identifies significant problems with one of the planned ARD external interfaces in the MCC. The special MPS processor as presently formulated by FOD appears inadequate for use as an ARD mass track comparison base. It is recommended that alternatives be evaluated by FOD and either the special MPS processor be revised or another comparison base of sufficient accuracy be provided in the MCC.

6.0 References

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- 3) "Orbital Flight Test Abort Region Determinator Level B Formulation", 23 September 1976, JSC Internal Note 76-FM-49
- 4) "Abort Region Determinator Level C Formulation Requirements", 17 February 1977, JSC Internal Note 77-FM-12
- 5) "Change Request 1 to ARD Level C Formulation Requirements", 18 April 1977
- 6) "Change Request 2 to ARD Level C Formulation Requirements", October 1977
- 7) "OFT Baseline Abort Plan", October 1977, JSC Internal Note 77-FM-53
- 8) "Abort Region Determinator/RTLS Event Predictor Mission Control Center Software Verification Test Plan", 9 September 1977, TM No. 1.4-6E-27
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- 10) "ARD Processor Test Data Base-MED Inputs Table", 29 July 1977, TM No. 1.4-6E-23
- 11) "OFT ARD Processor Test Data Base Systems Constants", 11 October 1977, TM 1.4-6E-29
- 12) "ARD Changes 5 and 6", 28 September 1977, TM No. 1.4-6E-28
- 13) "Ascent Reference Flight Profile for OFT-1", 7 March 1977, JSC Internal Note 77-FM-14

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- 15) "Abort Region Determinator (ARD) Display", GSR-217,
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8 October 1976, GSR-144
- 17) "MPAD Accuracy and Formulation Verification of ET Depletion Time-
to-GO Predictions", 14 December 1976, JSC Memorandum FM4(76-
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- 18) "Acceleration and Mass Estimation", 5 August 1975, C. S. Draper
Lab-John P. Higgins

TABLE (1): ARD Module Performance for Mean Wind OFT-1

1a) Abort Mode Boundary Prediction

Hypothetical Abort Type	Mode Boundary ARD	Mode Boundary *RFP	Difference ARD-*RFP Sec
AOA	211	213.	-2.
ATO	245.	245.	0.
MC	295.	300.	-5.
RTLS	291.	** 290.	1.

*RFP - Values listed in the Ascent Reference Flight Profile for OFT-1;
March 7, 1977; JSC Internal Note No. 77-FM-14

** - RFP consistent results for 12 degree/second pitch rate from
Reference 14

1b) Nominal Margin Prediction

Elapsed Time From Liftoff (Sec)	ARD Predicted Nom AM Margin	Error ARD-*RFP
0.0	343	-203
52	385	-161
100	510	-36
126	535	-11
176	547	1
227	537	-9
277	543	-3
327	551	5
377	551	5
427	552	6
477	545	-1.
512	537	-9

* RFP margin from Reference 13 is 11205 lbs or 546 feet per second

TABLE (2): ARD MODULE PERFORMANCE FOR NO WIND OFT-1

2a) ARD Nominal AM Prediction Versus SVDS Results

PET SEC	ARD NOM AM MARGIN FT/S	SVDS FT/S	ERROR ARD- SVDS FT/S	ARD PREDICTED MECO TIME SEC	ACTUAL MECO SVDS SEC	ERROR MECO SVDS SEC
0.0	607.7	647.2	-39.5	523.4	522.9	.5
49.0	634.9	647.2	-12.3	522.1	522.9	.2
98.0	673.6	647.2	26.4	522.7	522.9	-0.2
126.7	684.5	647.2	37.3	522.6	522.9	-0.3
152.7	671.8	647.2	24.6	522.7	522.9	-0.2
200.7	662.4	647.2	15.2	522.7	522.9	-0.2
213.0	659.8	647.2	12.6	522.8	522.9	-0.1
243.0	655.9	647.2	8.7	522.9	522.9	0.0
249.0	655.8	647.2	8.6	522.9	522.9	0.0
297.0	653.3	647.2	6.1	522.9	522.9	0.0
351.0	653.6	647.2	6.4	522.9	522.9	0.0
369.0	654.5	647.2	7.3	522.9	522.9	0.0
399.0	648.8	647.2	1.62	523.0	522.9	0.1
417.0	656.3	647.2	9.1	522.9	522.9	0.0
453.0	656.3	647.2	9.1	522.9	522.9	0.0
519.0	640.4	647.2	-6.8	523.0	522.9	0.1

TABLE (2): ARD MODULE PERFORMANCE FOR NO WIND OFT-1 (CONTINUED).

2b) ARD Abort Availability Predictions Versus SVDS Results

ABORT MODE	PET SEC	ARD HM MARGIN FPS	SVDS RESULT FPS	ARD ERROR FPS
AOA	213	132.3	116.0	16.3
AOA	369	882.1	859.6	22.5
ATO	243	139.6	150.0	-10.4
ATO	417	581.4	568.4	13.0
MC	297	196.9	194.0	2.9
MC	417	581.6	568.6	13.0
RTLS	171	9243.	9337	7
RTLS	249	3481	3521	-40
RTLS	267	1861	1866	-5
RTLS	300	-1563	-1551	12

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TABLE (3): ARD Second Stage Predictor Accuracy

P.E.T (seconds)	ARD Predicted MECO Time sec.	*Error SEC (ARD - SVDS)
126.7	522.61	-.33
152.7	522.74	-.20
200.7	522.70	-.24
249.0	522.88	-.06
297.0	522.93	-.01
351.0	522.92	-.02
399.0	522.97	+.03
447.0	522.91	-.03
501.0	522.96	+.02
519	522.97	+.03

* SVDS results: TMECO=522.94

TABLE (4): Ascent Numerical Integrator Accuracy

PARAMETER	SDVS	ANI INTEGRATING FROM 0 SECONDS	ANI- SDVS	ANI INTEGRATING FROM 24 SECONDS	ANI- SDVS	ANI INTEGRATING FROM 49 SECONDS	ANI- SDVS	ANI INTEGRATING FROM 75 SECONDS	ANI- SDVS	ANI INTEGRATING FROM 98 SECONDS	ANI- SDVS	ANI INTEGRATING FROM 122 SECONDS	ANI- SDVS
γ (degrees)	26.9515	27.163	-.211	27.198	.246	27.191	.239	27.009	.0575	26.958	-.0065	27.083	-.13
V_E fps	4243.9	4249.8	5.9	4243.6	-.3	4241.0	-2.9	4241.5	-2.4	4240.3	-3.6	4244.4	.5
V_i fps	5244.5	5293.4	48.9	5282.9	38.4	5272.7	28.2	5263.7	19.2	5250.3	5.8	5246.4	1.9
$\bar{V}_i$ fps	164.4 -4225.1 3102.6	65.4 -4409.2 2928.3	-99 -184.1 -174.3	70.4 -4386.6 29434.2	-94 -161.5 -159.4	84.4 -4352.4 2975.0	-80 -127.3 -127.6	115.4 -4311.0 3018.0	-49 -85.9 -84.6	139.0 -4258.8 3067.4	-25.4 -33.7 -35.2	140.9 -4230.2 3100.1	-23.5 -5.1 -2.5
R_i ft	21052207.	21054256.	2048.	+21054009	1801.	21053721	1513.	21052676	468.	21052292	84.	21052238	30.
$\bar{R}_i$ ft	-18236443. -2861585. 10121212	-18242971. -2872055. 10110739.	6528. -10470. -10473	-18242024. -2869545. 10112645.	5581. -7961. -8567	-18240500. -2866703. 10115599.	4057. -5118 -5613	-18238044. -2864339. 10118522.	1601. -2754 -2690.	-18236815. -2862170. 120120552.	372. -585 -660	-18236491. -2861599. 10121191.	48. 6 -21
W lbs	1499227	1499244	17.0	1499243	16.0	1499377.6	150.6	1499319.5	92.5	1499318.1	91.1	1499316.7	89.7
ET .lbs FUEL	1204422.1	1204439.	16.9	1204437.8	15.7	1204572.6	150.5	1204514.5	92.4	1204513.1	91.0	1204511.7	89.6
NOM VAM fps	647.2	607.7	-40.0	614.8	-32.4	635.0	-12.2	655.0	7.8	673.6	26.4	691.6	44.4

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TABLE (5): ARD Mass Track Accuracy

PET	SVDS WT.	ARD WT.	ARD-SVDS	ET SVDS WT	ET ARD WT	ARD-SVDS
0	4439479.9	4439486.	6.1	1558092.0	1558093.	0
49.0	3245948.0	3246040.	92.	1424375.2	1424453.	78.
98.0	2206437.4	2206328.	-109.	1293280.3	1293358.	78.
152.7	1418682.3	1418759.	77.	1123877.3	1123954.	77.
200	1269984.3	1270061.	76.	975179.31	975256.	76.
249	1120306.3	1120384.	77.	825501.3	825579.	77.
303	953021.03	953099.	77.	658216.05	658294.	77.
351	804323.03	804400.	77.	509518.05	509595.	76.
399	652527.15	655702.	31	357722.1	360897.	31.
447	506927.04	507004.	77	212122.05	212199.	76.
501	356192.58	356128	-64	61387.59	61323.	-64.
519	316316.46	316206.	-110	21511.476	21401.	-110

TABLE (6): ARD Module Performance for MC
(76% Partial Trust)

6a) Nominal Margin Prediction

PET SEC	ARD NOMINAL MARGIN FT/SEC	SVDS FT/SEC	ERROR (ARD-SVDS) FT/SEC	MECO TIME ARD SEC	MECO SVDS SEC	ERROR ARD-SVDS SEC
74.0	136.3	143.4	-7.1	562.5	561.7	.08
152.7	157.3	143.4	13.9	561.8	561.7	.1
200.7	172.1	143.4	28.7	561.5	561.7	-.2
248.7	172.5	143.4	29.1	561.6	561.7	-.1
303.0	163.9	143.4	20.5	561.6	561.7	-.1
399.0	155.8	143.4	12.4	561.6	561.7	-.1
453.0	152.4	143.4	9.0	561.7	561.7	.0
501.0	123.61	143.4	-19.8	561.7	561.7	.0
549.0	122.7	143.4	-20.7	561.7	561.7	.0
561.0	111.1	143.4	-32.3	561.9	561.7	.2

6b) ARD-Predicted Mode Boundary Shift

ABORT TYPE	BOUNDARY AFTER FAILURE (SEC)	*RFP BOUNDARY (SEC)	BOUNDARY SHIFT (SEC)
AOA	283	213	70
ATO	426	245	181
MC	426	300	126
RTLS	309	290	19

* Reference 13

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TABLE (7): ARD Module Performance for ATO Abort of No-Wind OFT-1

PET SEC	ARD ATO MARGIN FT/SEC	SVDS RESULT FT/SEC	ARD ERROR ARD-SDVS FT/SEC	ARD PREDICTED TIME SEC	ACTUAL MECO SVDS SEC	ERROR ARD-SDVS SEC
249.6	167.5	152.1	15.3	-	617.8	-
255.0	164.5	152.1	12.4	-	617.8	-
261.0	163.3	152.1	11.2	618.8	617.8	1.0
267.0	158.3	152.1	6.2	618.8	617.8	1.0
273.0	128.4	152.1	-23.7	618.0	617.8	.2
303.0	126.6	152.1	-25.4	618.0	617.8	.2
327.0	124.6	152.1	-27.5	618.0	617.8	.2
351.0	125.5	152.1	-26.6	618.0	617.8	.2
399.0	123.3	152.1	-28.8	617.4	617.8	-.4
453.0	128.5	152.1	-23.6	617.9	617.8	.1
501.	134.5	152.1	-17.6	617.8	617.8	0.0
549.	145.4	152.1	-6.7	617.8	617.8	0.0
615.	150.2	152.1	-1.9	617.8	617.8	0.0

TABLE (8): ARD Module Performance for AOA Abort of Mean-Wind OFT-1

PET SEC	ARD AOA MARGIN FT/SEC	SVDS RESULT FT/SEC	ERROR ARD-SVDS FT/SEC	ARD PREDICTED MECO TIME SEC	ACTUAL MECO SVDS SEC	ERROR MECO ARD-SVDS SEC
237.0	4.0	42.9	-38.9	632.1	631.4	.7
243.0	6.7	42.9	-36.2	632.1	631.4	.7
273.0	3.8	42.9	-39.1	631.7	631.4	.3
303.0	9.5	42.9	-33.4	631.7	631.4	.3
351.0	19.2	42.9	-23.0	631.6	631.4	.2
399.0	23.7	42.9	-19.2	631.5	631.4	.1
447.0	29.9	42.9	-13.0	631.6	631.4	.2
519.	34.0	42.9	-8.9	631.5	631.4	.1

TABLE (9): ARD Module Performance For RTLS Abort of Mean-Wind OFT-1

PET SEC	ARD RTLS MARGIN FT/SEC	SVDS RESULT FT/SEC	ERROR (ARD-SVDS) FT/SEC
459	370*	298	72*
507	317	298	19
555	301	298	3
603	303	298	5
651	303	298	5
705	298	298	0

* Reflects vehicle performance if 96% throttle had been maintained from end of turn to start of powered pitchdown. Ground and onboard throttle were adjusted to 95% throttle at 505 seconds.

TABLE (10): ARD Characteristics Table

PARAMETER	PARAMETER DESCRIPTION	VALUE
M_{NOMHM}	Nominal 2-SSME HM margin slope at mode boundry	7.17 ft/s ²
M_{ATOHM}	ATO 2-SSME HM margin slope at mode boundry	8.91 ft/s ²
M_{AOAHM}	AOA2-SSME HM margin	11.14 ft/s ²
M_{OTLSHM}	RTLS margin slope at mode boundary	103.16 ft/s ²
V_{NOMAM} MEAN WIND	Non-dispersed second stage nominal AM margin for mean first stage winds	546.0 ft/sec
V_{NOMAM} NO WIND	Non-dispersed nominal AM margin for no winds	684.5 ft/sec
$V_{L/O}$ NOM HM	Liftoff nominal 2-SSME HM margin	-2799.2 ft/s
$V_{L/O}$ ATO HM	Liftoff ATO 2-SSME HM margin	-2486.5 ft/s
$V_{L/O}$ AOA HM	Liftoff AOA 2-SSME HM margin	-2204.1 ft/s
$V_{L/O}$ RTLS HM	Liftoff RTLS 2-SSME HM margin	12203.0 ft/s
V_{EAOA} DELAY	Early AOA abort enactment delay penalty	-.55 ft/sec
V_{AOA} SWITCH	AOA target switch velocity	7292 ft/sec
V_{ATO} SWITCH	ATO target switch velocity	9230. ft/sec
FPR	Mission FPR not considered in ARD margins	262.1 ft/sec
TOLERANCE	ARD module worst case margin uncertainty	40 ft/sec

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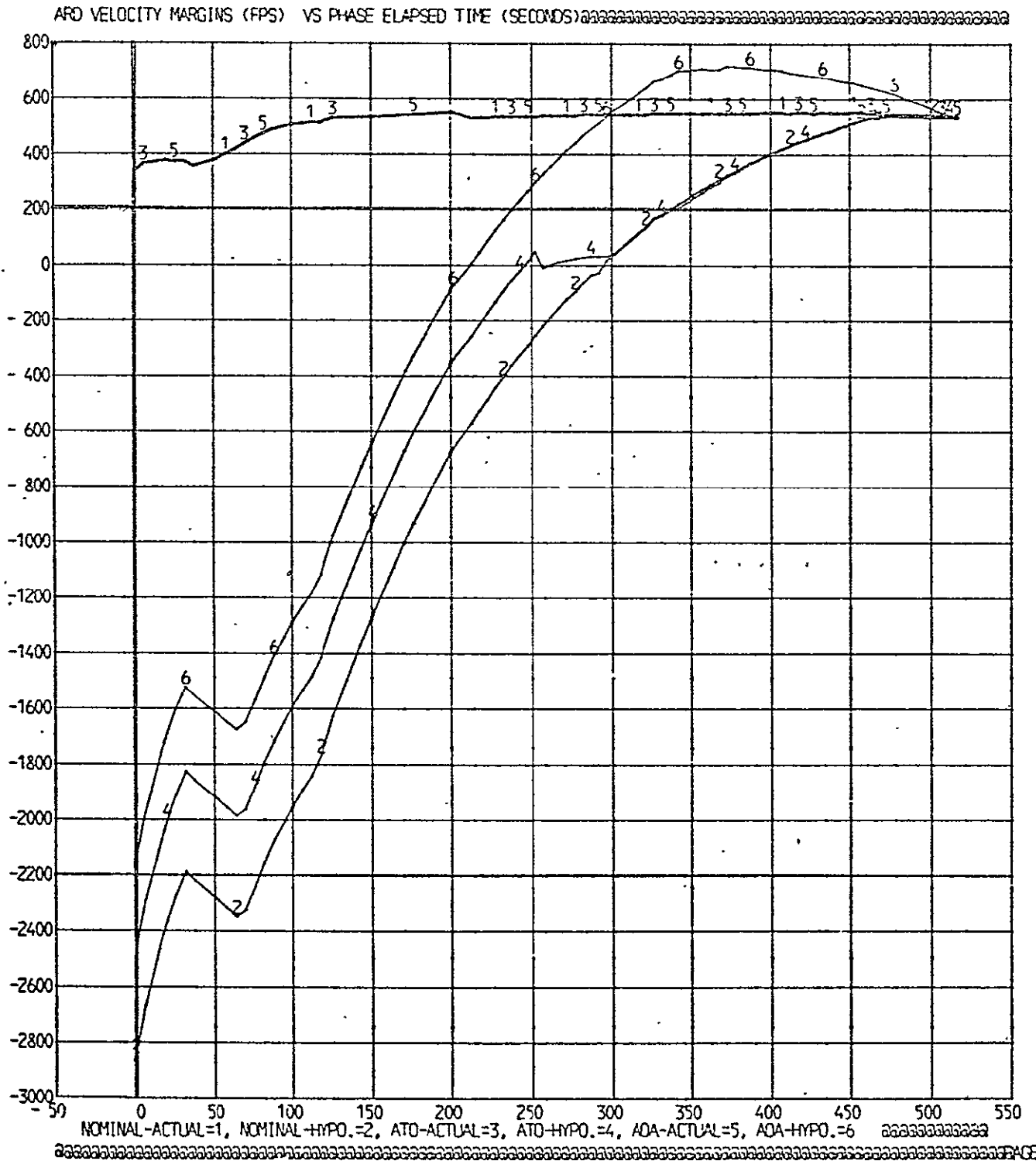


FIGURE 1.1: Mean-Wind OFT-1 Ascent - ARD Downrange Margin Histories

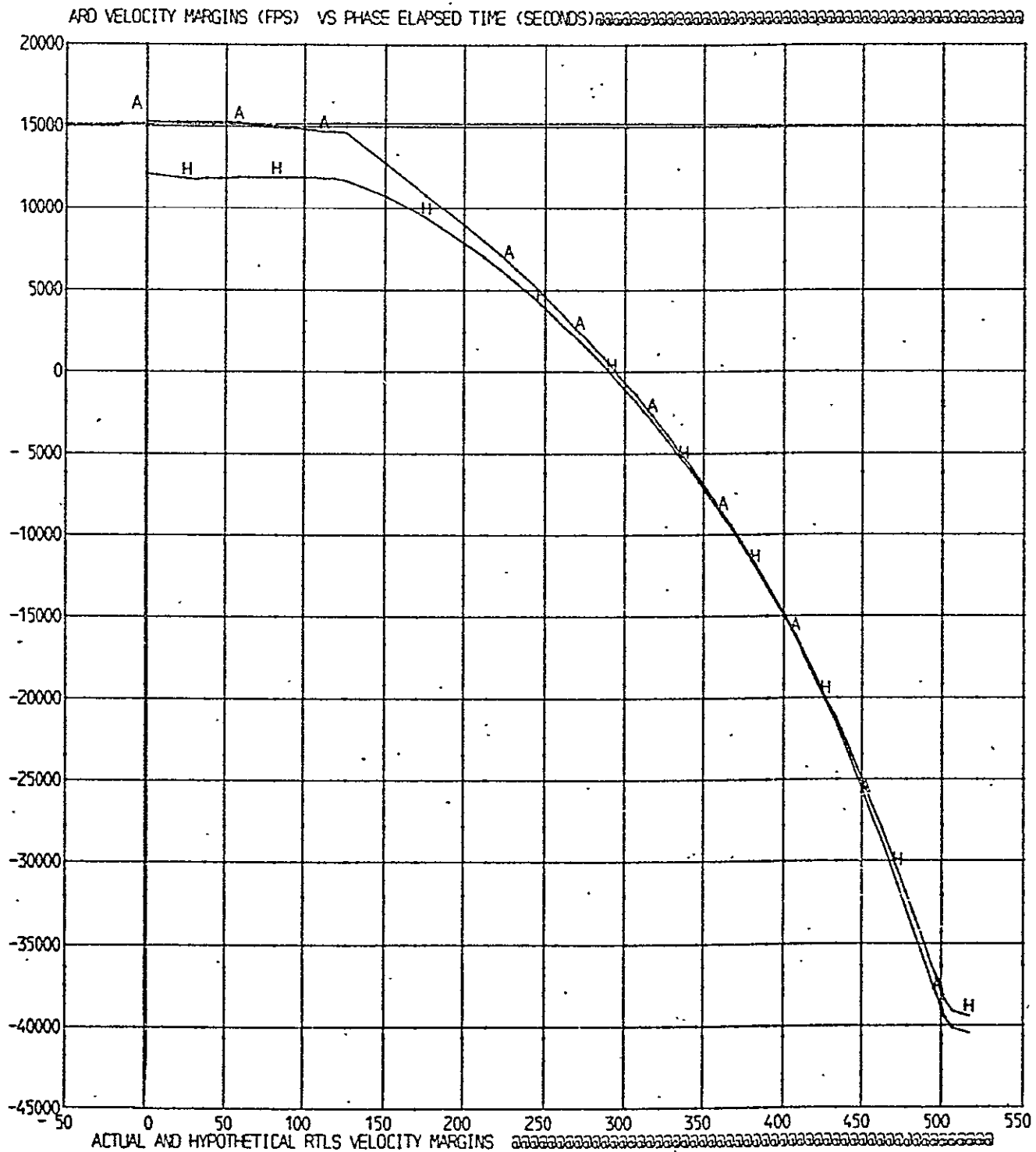


FIGURE 1:2: Mean-Wind OFT-1 Ascent - ARD RTLS Margin Histories

ABORT REGION DETERMINATOR

PET 58.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES

THROTTLES

COMMANDER .0 ABORT
L C R SEL

TLM .00 .00 .00 NOM
ARD .63 .63 .63

HYPOTHETICAL .00 1.09 1.09

VEL MARGINS

VEL MARGINS

REGION MPROP XOMS SUM

REGION MPROP XOMS SUM

NOM 400.37 .00 .00

NOM -2317.80 .00 .00

RTLS 15283.81 15283.81

RTLS 11938.37 11938.37

AOA 400.55 .00 .00

AOA -1646.25 .00 .00

ATO 400.55 .00 .00

ATO -1955.54 .00 .00

EVENT TLM ARD

RTLS EVENT PREDICTION

TGO .0 467.5
MECO .00 525.55
TMECO .0 .0
VMECO 0. 25668.

DELO DISS .0 TMECO .0
TIME TO TURN .00 RMECO .0
PLT TURN .00 VMECO .0
TIME END TURN .00 GMECO .0

PRPLT OMS RCS CURRENT WT I
LBS 17584. 3797. VEH3067720.1
DELV 58. ETP1406745.1

DELHT PITCH .0
MECO-IS .0
PITCHDOWN Z .0

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FIGURE 1.3 CONTINUED

ABORT REGION DETERMINATOR

PET 126.0 SELECTED SOURCETLM GMT L/045000.0

ACTUAL MODE

II

HYPOTHETICAL MODE

THROTTLES

ABORT
SEL

III

THROTTLES

COMMANDED
L

	C	R
0	00	00
0	1.00	1.00

-NOM-

HYPOTHETICAL	.00	1.09	1.09
--------------	-----	------	------

VEL MARGINS			
REGION	MPR-OP	XOMS	SUM

11-1

VEL MARGINS			
REGION	MPROP	XOMS	SUM

NOM	535.29	.00	.00
-----	--------	-----	-----

二

NOM -1625.73 .00 .00

~~RTLS-14722.08~~ 14722.08

二

~~RTLS11-779.76~~ ~~11-779.76~~

AOA	535.09	.00	.00
-----	--------	-----	-----

I

AOA	-979.74	.00	.00
-----	---------	-----	-----

ATO 535.09 00 00

1

ATO -1277.47.....CO.....00

EVENT	TLM	ARD
-------	-----	-----

I

RTLS EVENT PREDICTION

TGO	.0	398.1
MECO	.00	524.12
TME0	.0	.0
VME0	0.	25668.

III

DELO DISS	.00	TIME CO	.00
TIME TO TURN	.00	RMECO	.00
PET TURN	.00	VMECO	.00
TIME END TURN	.00	GMECO	.00

PRPLT	OMS	RCS	CURRENT WT .I
LBS	17584.	3797.	VEH1501343.I
DELV	119.	WZPLN	ETP1206538.I

DELTH PITCH	.0
MECO-IS	.0
PITCHDOWN Z	.0

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FIGURE 1.3 CONTINUED

ABORT REGION DETERMINATOR

PET 212.0 SELECTED SOURCETLM GMT L/045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMAND	L	C	R	ABORT SEL	L	C	R
TLM	1.00	1.00	1.00	NOM	1.00	1.09	1.09
ARD	1.00	1.00	1.00				

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	534.39	.00	534.39	NOM	-571.86	.00	-571.86
RTLS	8072.83		8072.83	RTLS	7065.88		7065.88
AOA	533.90	319.32	853.22	AOA	5.07	.00	5.07
ATO	533.90	145.10	679.00	ATO	-257.28	.00	-257.28

EVENT			RTLS EVENT PREDICTION		
TLM	ARD		DELO DISS	TMECO	
TGO	.0	312.1	.0	TMECO	.0
MECO	.00	524.09	.00	RMECO	.0
TME0	.0	.0	.00	VMECO	.0
VME0	0.	25668.	.00	GMECO	.0

PRPLT	OMS	RCS	CURRENT WT	1	DELTHY PITCH	.0
LBS	17584.	3797.	VEH1234926.	I	MECO-IS	.0
DELV	145.		ETP 940121.	I	PITCHDOWN Z	.0

FIGURE 1.3 CONTINUED

ABORT REGION DETERMINATOR

PET 247.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMANDED	L	C	R	ABORT SEL	L	C	R
TLM	.00	.00	.00	NOM			
ARD	1.00	1.00	1.00		HYPOTHETICAL	.00	1.09 1.09

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	538.76	.00	538.76	NOM	-290.12	.00	-290.12
RTLS	4970.63		4970.63	RTLS	4230.78		4230.78
AOA	538.94	319.32	858.26	AOA	265.11	.00	265.11
ATO	538.94	145.10	684.04	ATO	14.97	.00	14.97

EVENT TLM ARD			RTLS EVENT PREDICTION		
TGO	.0	277.1	DELO DISS	.0	TMECO .0
MECO	.00	524.07	TIME TO TURN	.00	RMECO .0
TMFO	.0	.0	PET TURN	.00	VMECO .0
VMFO	.0	25668.	TIME END TURN	.00	GMECO .0

PKPLT	OMS	RCS	CURRENT WT	DELTHT PITCH	.0
LBS	17584.	3797.	VEH1126500.I	MECO-IS	.0
DELV	159.	159.	ETP 831695.I	PITCHDOWN Z	.0

FIGURE 1.3 CONTINUED

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ABORT REGION DETERMINATOR

PET 292.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES					THROTTLES				
COMMAND	L	C	R	ABORT SEL					
TLM	.00	.00	.00	NOM					
ARD	1.00	1.00	1.00						

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	544.11	.00	544.11	NOM	-25.28	.00	-25.28
RTLS	347.59		347.59	RTLS	-112.63		-112.63
AOA	544.10	319.32	863.42	AOA	515.53	.00	515.53
ATO	544.10	145.10	689.20	ATO	34.32	116.90	151.22

EVENT			RTLS EVENT PREDICTION		
TGO	.0	232.2	DELO DISS	.0	TMECO
MECO	.00	524.20	TIME TO TURN	.00	RMECO
TMECO	.0	.0	PET TURN	.00	VMECO
VMECO	0.	25668.	TIME END TURN	.00	GMECO

PRPLT	OMS	RCS	CURRENT WT	DELTHT PITCH
LBS	17584.	3797.	VEH 987096.	MECO-IS
DELV	181.		ETP. 692291.	PITCHDOWN Z

FIGURE 1.3 CONTINUED

ABORT REGION DETERMINATOR

PET 502.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMANDED	L	C	R	ABORT SEL	L	C	R
TLM	.00	.00	.00	NOM	.00	1.09	1.09
ARD	.75	.75	.75				

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	539.15	.00	539.15	NOM	544.80	.00	544.80
RTLS*****			39506.11	RTLS*****			38437.32
AOA	539.07	319.32	858.38	AOA	566.52	290.55	857.08
ATO	539.06	145.10	684.16	ATO	544.70	145.10	689.80

EVENT TLM ARD			RTLS EVENT PREDICTION			
TGO	.0	22.0	DELO DISS	.0	TMECO	.0
MECO	.00	524.01	TIME TO TURN	.00	RMECO	.0
TME0	.0	.0	PET TURN	.00	VMECO	.0
VME0	0.	25668.	TIME END TURN	.00	GMECO	.0

PRPLT	OMS	RCS	CURRENT WT	DELTHT PITCH	.0
LBS	17584.	3797.	VEH 353723.1	MECO-IS	.0
DELV	514.	ETP	58918.1	PITCHDOWN Z	.0

FIGURE 1.3 CONTINUED

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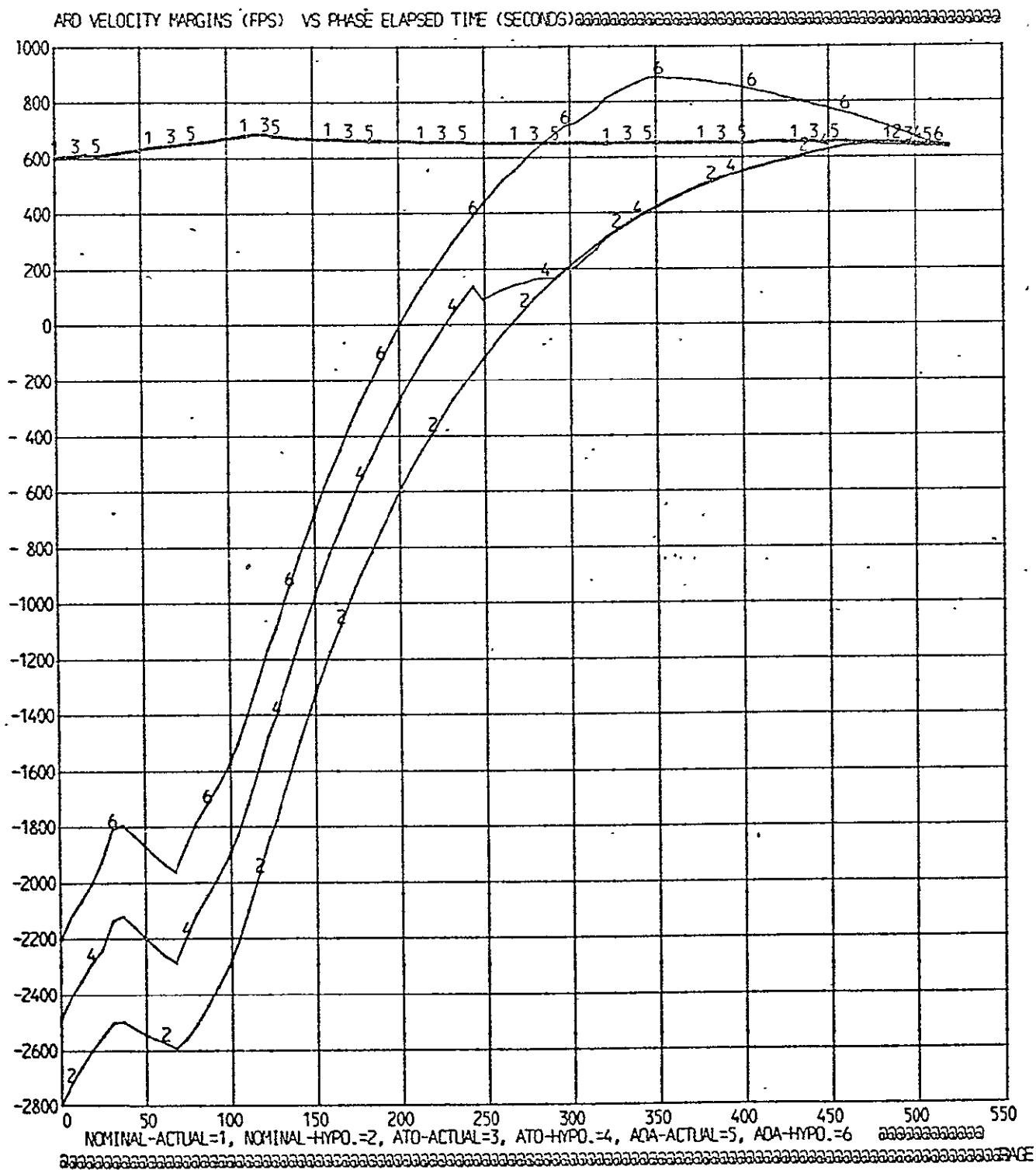


FIGURE 1.4: No-Wind OFT-1 Ascent - ARD Downrange Margin Histories

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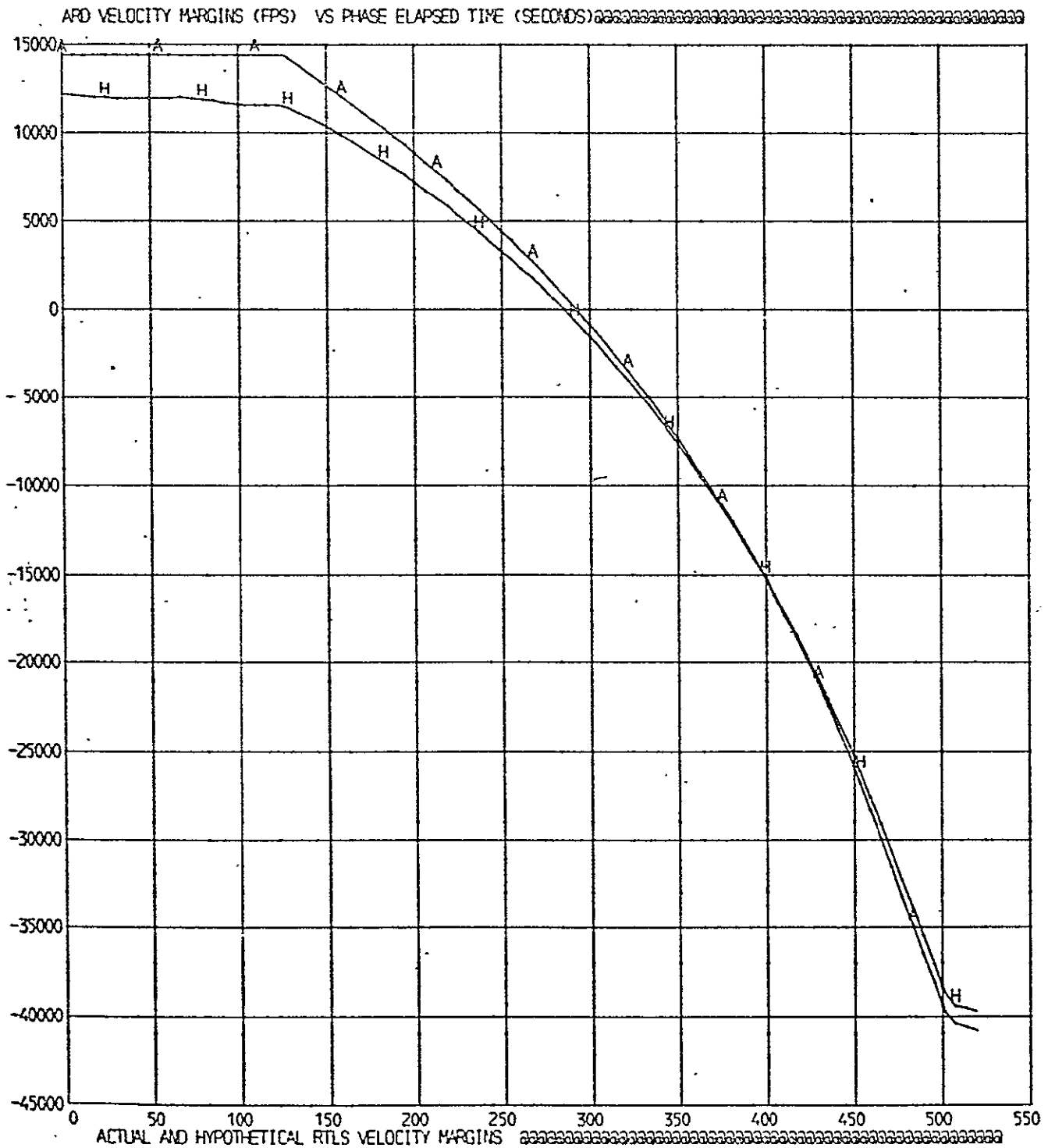


FIGURE 1.5: No-Wind OFT-1 - ARD RTLS Margin Histories

ABORT REGION DETERMINATOR

PET .00 SELECTED SOURCE TLM GMT L7045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES

THROTTLES

COMMANDED

ABORT

L C R

SEL

TLM .00

.00

.00

.00

NOM

L

C

R

ARD 1.00

1.00

1.00

1.00

HYPOTHETICAL

.00

1.09

1.09

REGION

MPROP

XOMS

SUM

REGION

MPROP

XOMS

SUM

NOM

607.71

.00

.00

NOM

-2799.20

.00

.00

RTLS

14398.49

14398.49

RTLS

12203.08

12203.08

AOA

607.75

.00

.00

AOA

-2204.14

.00

.00

ATO

607.75

.00

.00

ATO

-2486.53

.00

.00

EVENT TLM

ARD

RTLS EVENT PREDICTION

TGO

.00

523.4

I

DELO DISS

.00

TMECO

.00

MECO

.00

523.39

I

TIME TO TURN

.00

RMECO

.00

TMEO

.00

.00

I

PET TURN

.00

VMECO

.00

VMEO

0.00

25668.00

I

TIME END TURN

.00

GMECO

.00

PRPLT

OMS

RCS

CURRENT WT

I

DELTHT PITCH

.00

LBS

17584.00

3797.00

VEH4439486.00

I

MECO-IS

.00

DELV

40.00

ETP1558093.00

I

PITCHDOWN Z

.00

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FIGURE 1.6: No-Wind OFT-1 ARD Digital Displays

ABORT REGION DETERMINATOR

PET 128.7 SELECTED SOURCE TLM GMT L7045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMAND	L	C	R	ABORT SEL	L	C	R
TLM	.00	.00	.00	NOM	.00	1.09	1.09
ARD	1.00	1.00	1.00				

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	682.66	.00	682.66	NOM	-1734.70	.00	-1734.70
RTLS	14264.70		14264.70	RTLS	11403.53		11403.53
AOA	682.13	319.33	1001.46	AOA	-1056.31	.01	-1056.30
ATO	682.13	145.10	827.23	ATO	-1365.36	.00	-1365.35

EVENT TLM ARD RTLS EVENT PREDICTION

TGO	.00	393.9	DELO DISS	.00	TMECO	.00
MECO	.00	522.62	TIME TO TURN	.00	RMECO	.00
TMECO	.00		PET TURN	.00	VMECO	.00
VMECO	0.	25668.	TIME END TURN	.00	GMECO	.00

PRPLY	OMS	RCS	CURRENT WT	DELTH PITCH	.00
LBS	17584.	3797.	VEH1493108.I	MECO-IS	.00
DELV	119.		ETP1198303.I	PITCHDOWN 2	.00

FIGURE 1.6 CONTINUED

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ABORT REGION DETERMINATOR

PET 200.7 SELECTED SOURCE TLM GMT L7045000.0

ACTUAL MODE

I HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMAND	L	C	R	ABORT SEL	L	C	R
TLM	.00	.00	.00	NOM	.00	1.09	1.09
ARD	1.00	1.00	1.00				

VEE MARGINS				VEE MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	662.39	.00	662.39	NOM	-586.98	.00	-586.98
RTLS	8821.28		8821.28	RTLS	7178.18		7178.18
AOA	661.62	319.33	980.95	AOA	6.12	.01	6.13
ATO	661.62	145.10	806.73	ATO	-262.60	.00	-262.60

EVENT TLM			RTLS EVENT PREDICTION		
TGO	.0	322.0	DELO DISS	.0	TMECO
MECO	.00	522.70	TIME TO TURN	.00	RMECO
TMECO	.0	.0	PET TURN	.00	VMECO
VMECO	0.	25668.	TIME END TURN	.00	GMECO

PRPLY	OMS	RCS	CURRENT WT	DELTH PITCH
LBS	17584.	3797.	VEH1270061.I	MECO-IS
DELV	140.		ETP 975256.I	PITCHDOWN Z

FIGURE 1.6 CONTINUED

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ABORT REGION DETERMINATOR

PET 225.0				SELECTED SOURCE TLM	GMT 17045000.0
ACTUAL MODE				I	HYPOTHETICAL MODE
THROTTLES				I	THROTTLES
COMMANDED	.0		ABORT	I	
L	C	R	SEL	I	
TLM	.00	.00	.00	NOM	L C R
ARD	1.00	1.00	1.00		HYPOTHETICAL .00 1.09 1.09
VEL MARGINS				I	VEL MARGINS
REGION	MPROP	XOMS	SUM	I	REGION MPROP XOMS SUM
NOM	658.66	.00	658.66	I	NOM -330.19 .00 -330.19
RTLS	6756.43		6756.43	I	RTLS 5368.36 5368.36
AOA	658.45	319.33	977.78	I	AOA 243.97 .01 243.98
ATO	658.45	145.10	803.56	I	ATO -14.15 .00 -14.15
EVENT TLM ARD				I	RTLS EVENT PREDICTION
TGO	.0	297.8		I	DELO DISS .0 TMECO .0
MECO	.00	522.80		I	TIME TO TURN .00 RMECO .0
TMEO	.0	.0		I	PET TURN .00 VMECO .0
VMEO	0.	25668.		I	TIME END TURN .00 GMECO .0
PRPLT	OMS	RCS	CURRENT WT	I	DELHT PITCH .0
LBS	17584.	3797.	VEH1194733.	I	MECO-IS .0
DELV	149.		ETP 899928.	I	PITCHDOWN Z .0

FIGURE 1.6 CONTINUED

ABORT REGION DETERMINATOR

PET 285.0 SELECTED SOURCE TLM GMT L7045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES					THROTTLES				
COMMANDED	L	C	R	ABORT SEL		L	C	R	
TLM	.00	.00	.00	NOM		.00	1.09	1.09	
ARD	1.00	1.00	1.00						

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	653.76	.00	653.76	NOM	128.92	.00	128.92
RTLS	803.32		803.32	RTLS	19.71		19.71
AOA	653.76	319.33	973.09	AOA	656.43	.01	656.44
ATO	653.76	145.10	798.86	ATO	167.26	120.27	287.54

EVENT TLM			EVENT PREDICTION		
TGO	.0	237.9	DELO DISS	.0	TMECO
MECO	.00	522.93	TIME TO TURN	.00	RMECO
TMECO	.0	.0	PET TURN	.00	VMECO
VMECO	0.	25668.	TIME END TURN	.00	GMECO

PRPLT	OMS	RCS	CURRENT WT	DELTH PITCH
LBS	17584.	3797.	VEH1008860.I	MECO-IS
DELV	177.		ETP 714055.I	PITCHDOWN Z

FIGURE 1.6 CONTINUED

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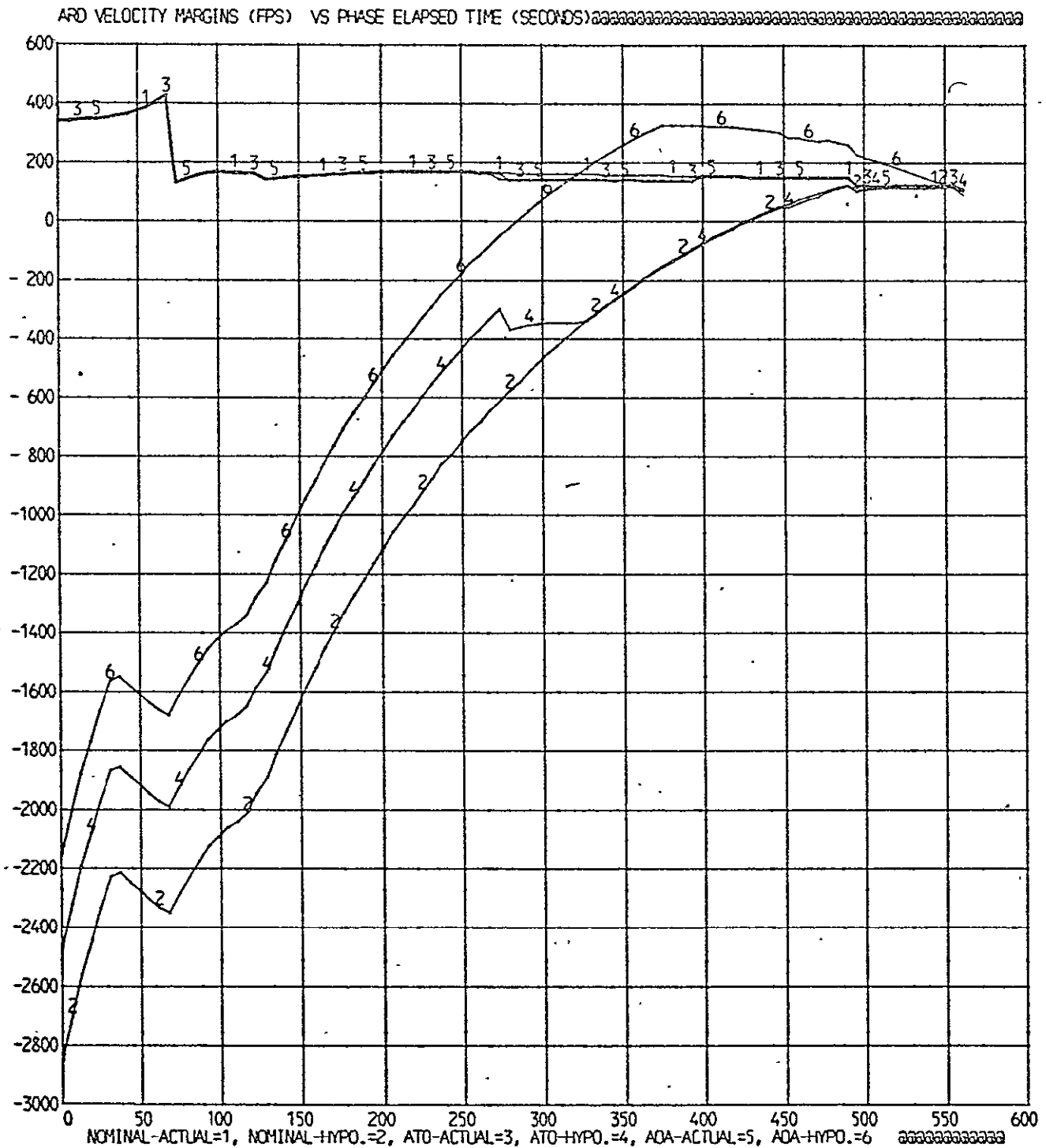


FIGURE 2.1: Mean-Wind OFT1 MC - Downrange Margin Histories for SSME-Partial-Loss-of-Thrust Failure

FIGURE 2.1: Mean-Wind OFT1 MC - Downrange Margin Histories
for SSME-Partial-Loss-of-Thrust Failure

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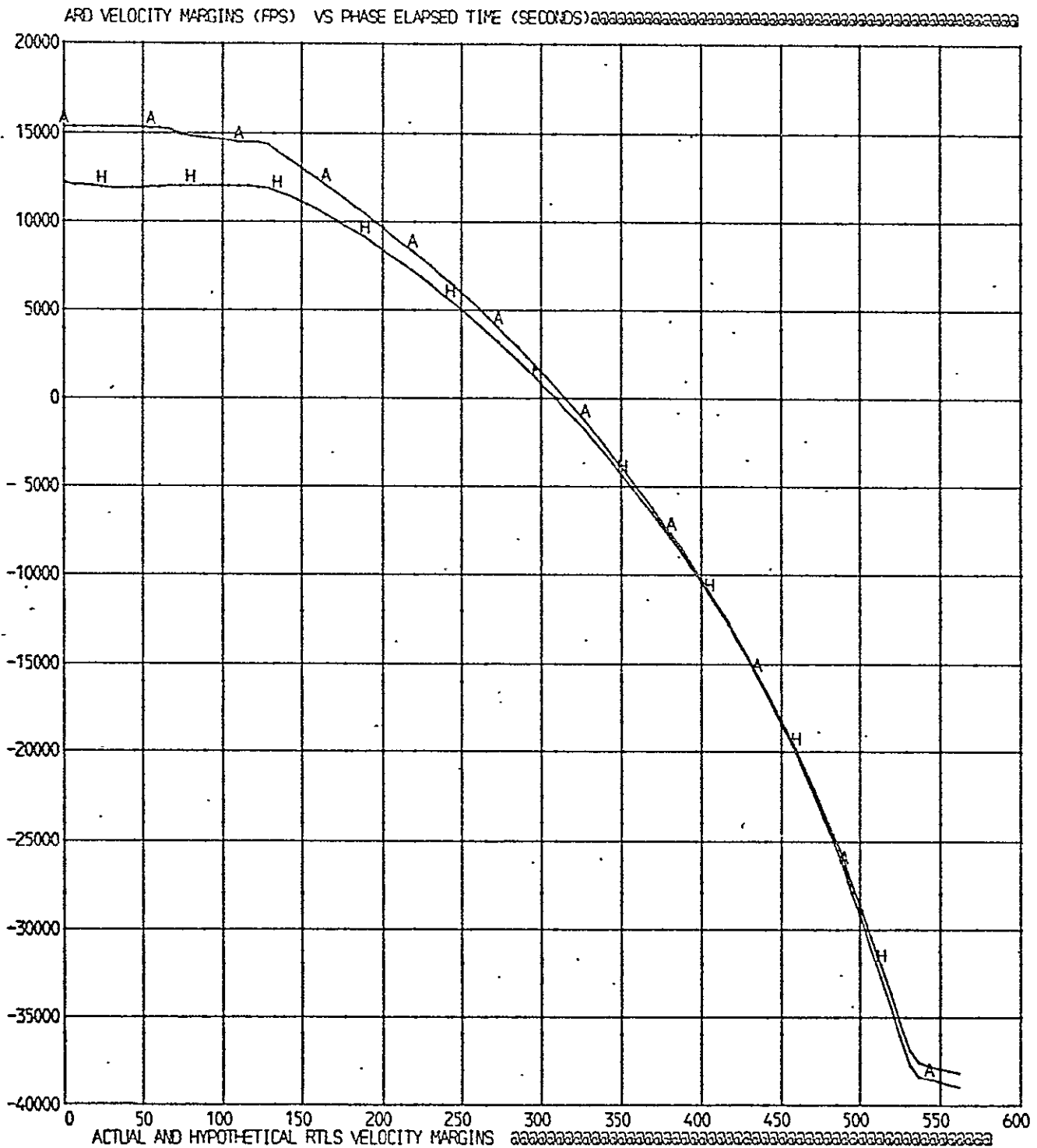


FIGURE 2.2: Mean-Wind OFT-1 MC - RTLS Margin Histories
For SSME-Partial-Loss-Of-Thrust

ABORT REGION DETERMINATOR

PET 74.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE I HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMAND	L	C	R	ABORT SEL	L	C	R
TLM	.00	.00	.00	NOM	.00	.00	.00
ARD	.76	1.00	1.00		HYPOTHETICAL	.00	1.09

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	136.32	.00	.00	NOM	-2296.18	.00	.00
RTLS	14951.27		14951.27	RTLS	11971.13		11971.13
AOA	135.95	.00	.00	AOA	-1613.78	.00	.00
ATO	135.95	.00	.00	ATO	-1923.51	.00	.00

EVENT TLM I RTLS EVENT PREDICTION

TCC	.00	448.5		DELO DISS	.00	TMECO	.00
MECO	.00	562.53		TIME TO TURN	.00	RMECO	.00
TMECO	.00	.00		PLT TURN	.00	VMECO	.00
VMECO	.00	25668.		TIME END TURN	.00	GMECO	.00

PRPLT	OMS	RCS	CURRENT WT	I	DELTHT PITCH	.00
L6S	17584.	3797.	VEH2727558.1	I	MECO-IS	.00
DELV	65.	3797.	ETP1369121.1	I	PITCHDOWN Z	.00

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FIGURE 2.3: ARD Digital Displays for OFT-1 MC with SSME Partial Loss of Thrust

ABORT REGION DETERMINATOR

PET 285.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMANDER	L	C	R	APORT SEL	L	C	R
TLM	.00	1.00	1.00	NOM			
ARD	.76	1.00	1.00		HYPOTHETICAL	.00	1.09

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	165.25	.00	165.25	NOM	-542.71	.00	-542.71
RTLS	2921.72		2921.72	RTLS	2172.07		2172.07
AOA	144.93	319.32	464.25	AOA	8.61	.00	8.61
ATO	145.21	145.10	290.31	ATO	-359.11	27.71	-331.41

EVENT TLM ARD 1 RTLS EVENT PREDICTION

TGO	.00	578.6		DELO DISS	.00	TMECO	.00
MECO	.00	561.58		TIME TO TURN	.00	RMECO	.00
TMECO	.00	.00		PET TURN	.00	VMECO	.00
VMECO	.00	2568.		TIME END TURN	.00	GMECO	.00

PRPLT	OMS	PCS	CURRENT WT	I	DELTH PITCH	.00
LBS	17584.	3797.	VEH100234.	I	MECO-IS	.00
DELV	109.	500000	ETP 765429.	I	PITCHDOWN Z	.00

FIGURE 2.3 CONTINUED

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ABORT REGION DETERMINATOR

PET 309.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE

HYPOTHETICAL MODE

COMMANDED THROTTLES

ABORT

THROTTLES

TLM L C R ARD SEL NOM

L C R HYPOTHETICAL L C R

REGION VFL MARGINS MPROP XOMS SUM

REGION VEL MARGINS MPROP XOMS SUM

NOM 164.14 .00 164.14

NOM -419.91 .00 -419.91

RTLS 610.83 .00 610.83

RTLS 1.40 .00 1.40

AOA 144.90 319.32 464.22

AOA 114.54 .00 114.54

ATO 145.15 145.15 290.25

ATO -343.78 96.52 -247.26

EVENT TLM ARD

RTLS EVENT PREDICTION

TGO .00 252.7
MECO .00 561.71
TME0 .00 .0
VME0 .00 25668.

DELO CESS .00 TMECO .0
TIME TO TURN .00 RMECO .0
PET TURN .00 VMECO .0
TIME END TURN .00 GMECO .0

PRPLT OMS RCS CURRENT WT I
LBS 17584. 3797. VEH 991798.1
DELV 180. 3140. LTP 696993.1

DELTH PITCH .0
MECO-IS .0
PITCHDOWN Z .0

FIGURE 2.3 CONTINUED

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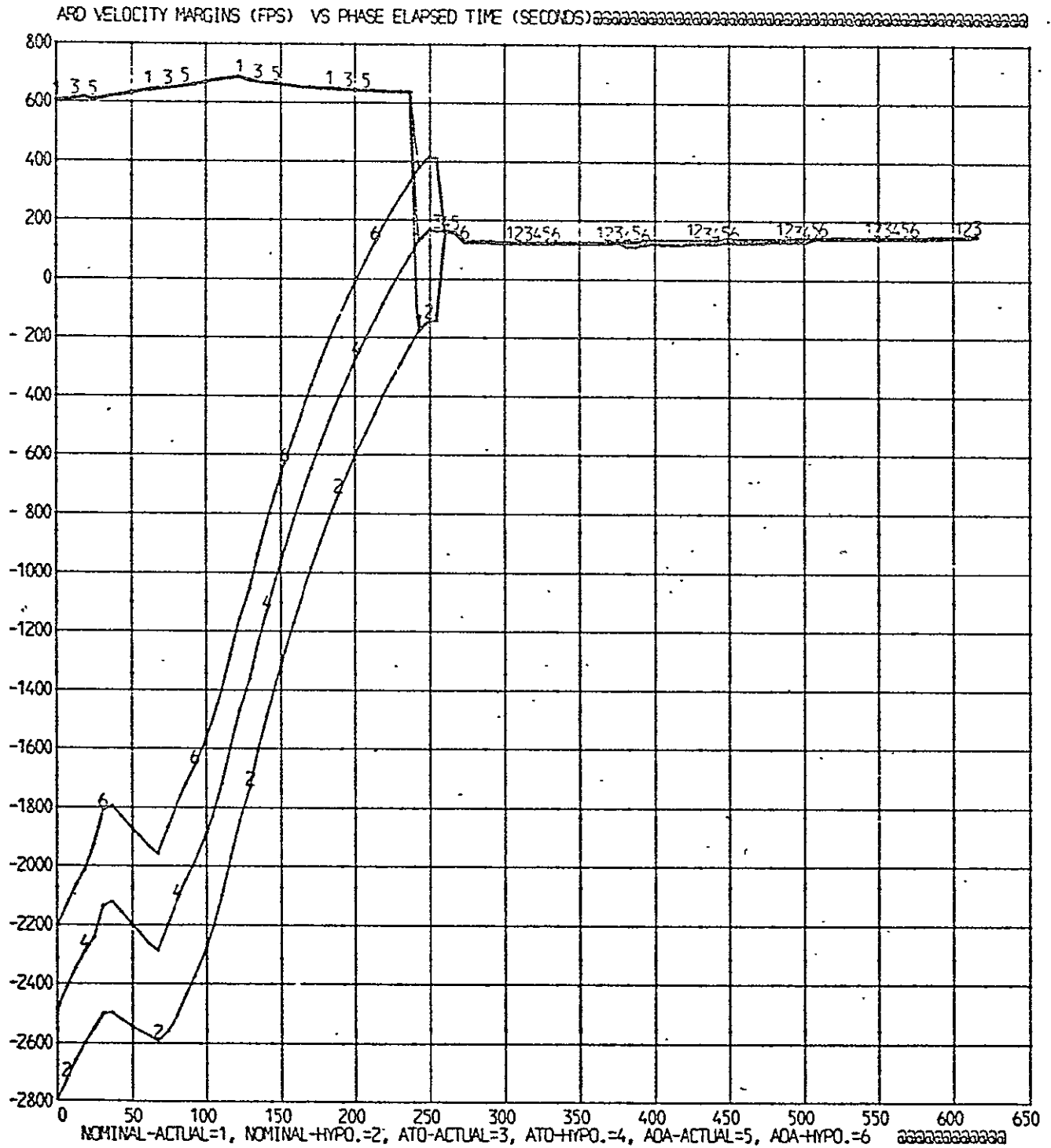


FIGURE 3.1: ATO - Aborted No-Wind OFT-1 - ARD Downrange
Margin Histories

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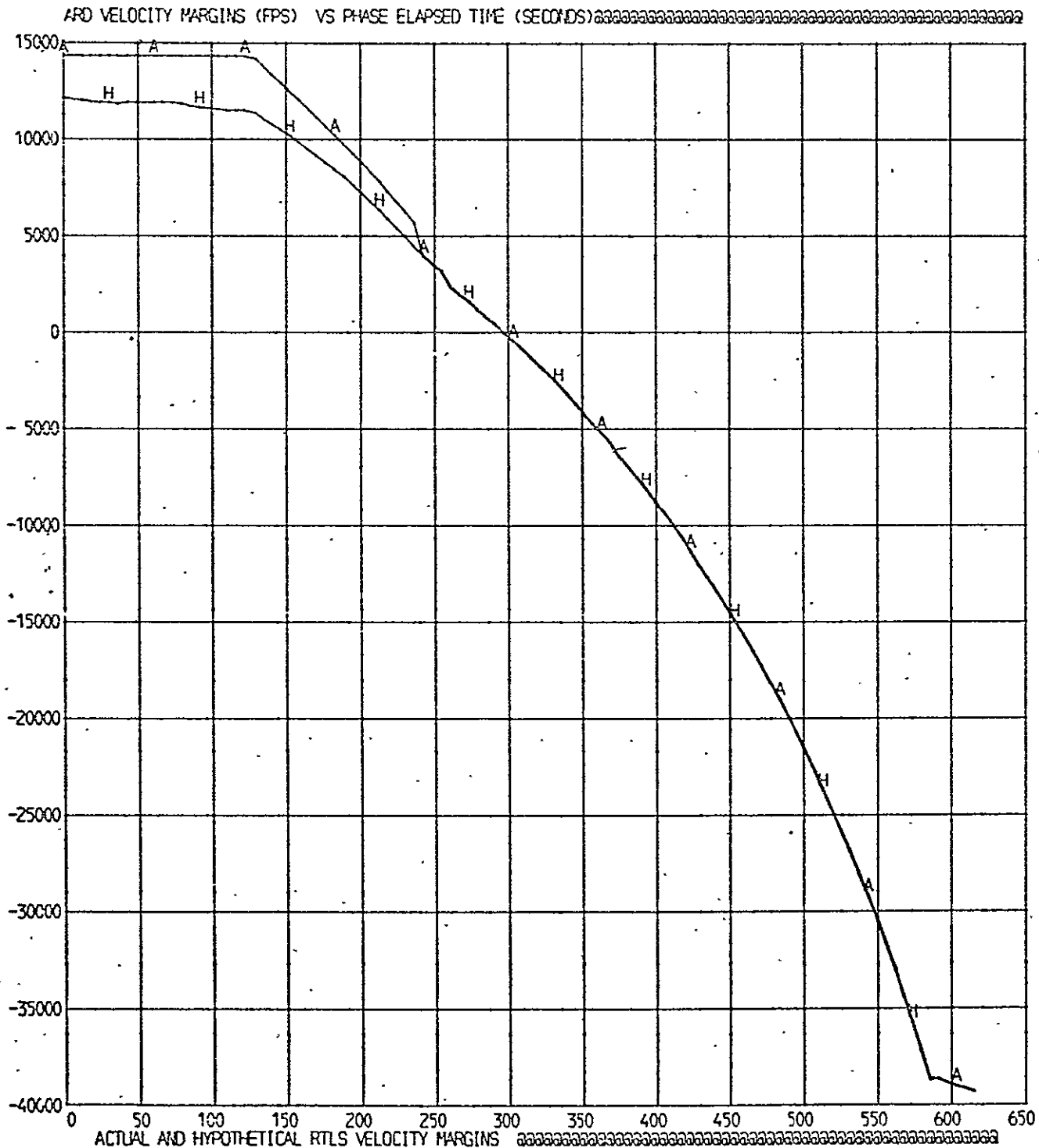


FIGURE 3.2: ATO - Aborted No-Wind OFT-1 - ARD RTLS
Margin Histories

ABORT REGION DETERMINATOR

PET 242.7				SELECTED SOURCETLM				GMT L7045000.0			
ACTUAL MODE				HYPOTHETICAL MODE							
THROTTLES				THROTTLES							
COMMANDER	.C	ABORT									
L	C	P	SEL								
TLM	.30	.30	.30	NOM							
ARD	.30	1.09	1.09		HYPOTHETICAL	.10	1.09				
VEL MARGINS				VEL MARGINS							
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM				
NOM	-175.66	.70	-175.66	NOM	-175.76	.30	-175.76				
RTLS	4026.76		4026.76	RTLS	4026.75		4026.75				
AOA	384.39	.01	384.40	AOA	384.39	.01	384.40				
ATO	133.43	.00	133.43	ATO	133.43	.00	133.43				
EVENT TLM ARD				RTLS EVENT PREDICTION							
TEO	.0	370.1		DELO DISS	.0	IMECO	.0				
MECO	.10	621.83		TIME TO TURN	.70	RMECO	.0				
TMEO	.0	242.7		PET TURN	.00	VMECO	.0				
VMFO	0.	6922.		TIME END TURN	.00	GMECO	.0				
PEPLT	CHS	RCS	CURRENT WT	DELTH PITCH	.0						
LBS	17584.	3797.	VEH1346580.	MECO-IS	.6						
DELV	157.	157.	EIP 845761.	PITCHDOWN Z	.J						

FIGURE 3.3: ATO - Aborted OFT 1 ARD Digital Displays

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ABORT REGION DETERMINATOR

PET 261.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMAND	TLM	ARD	ATO	COMMAND	TLM	ARD	ATO
COMMANDED	.00	1.09	1.09	HYPOTHETICAL	.00	1.09	1.09
VEL MARGINS				VEL MARGINS			
REGION	MPPROP	XCMS	SUM	REGION	MPPROP	XCMS	SUM
NOM				NOM			
RTLS				RTLS			
AOA				AOA			
ATO	163.23		163.29	ATO	163.29		163.29

EVENT TLM ARD RTLS EVENT PREDICTION

EVENT	TLM	ARD	RTLS	TIME TO TURN	PET TURN	TIME END TURN
TEO	.00	3.7.8				
MECO	.00	616.81				
TMEO	.00	242.7				
VMEO	.00	6922.				

PPPLT	GMS	RCS	CURRENT WT	DELHT PITCH
LES	17584.	3797.	VEH1899364.I	PECO-IS
DELV	142.		ETP 804659.I	PITCHDOWN Z

FIGURE 3.3 CONTINUED

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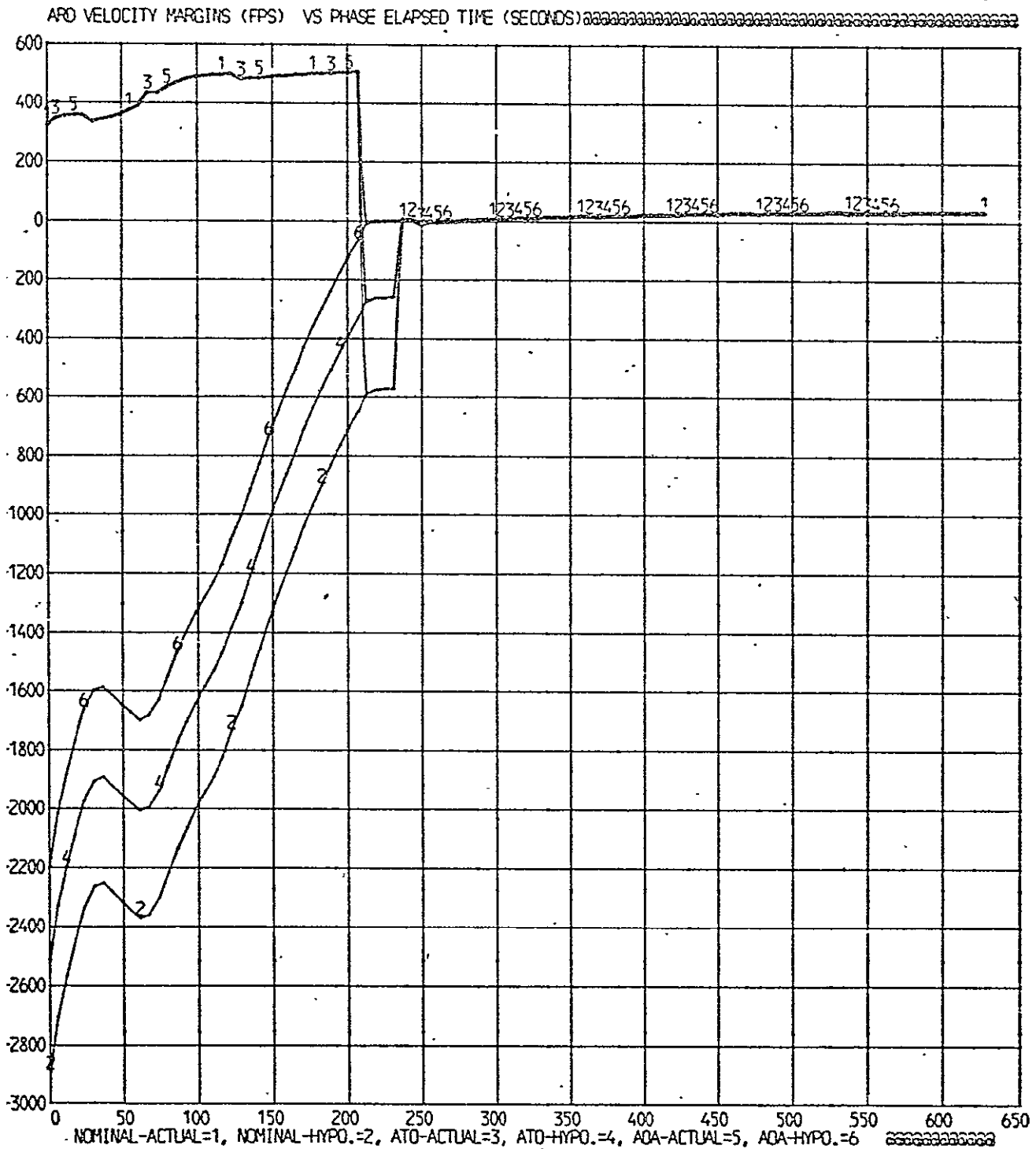


FIGURE 4.1: AOA-Aborted Mean-Wind OFT-1 - ARD
Downrange Margin Histories

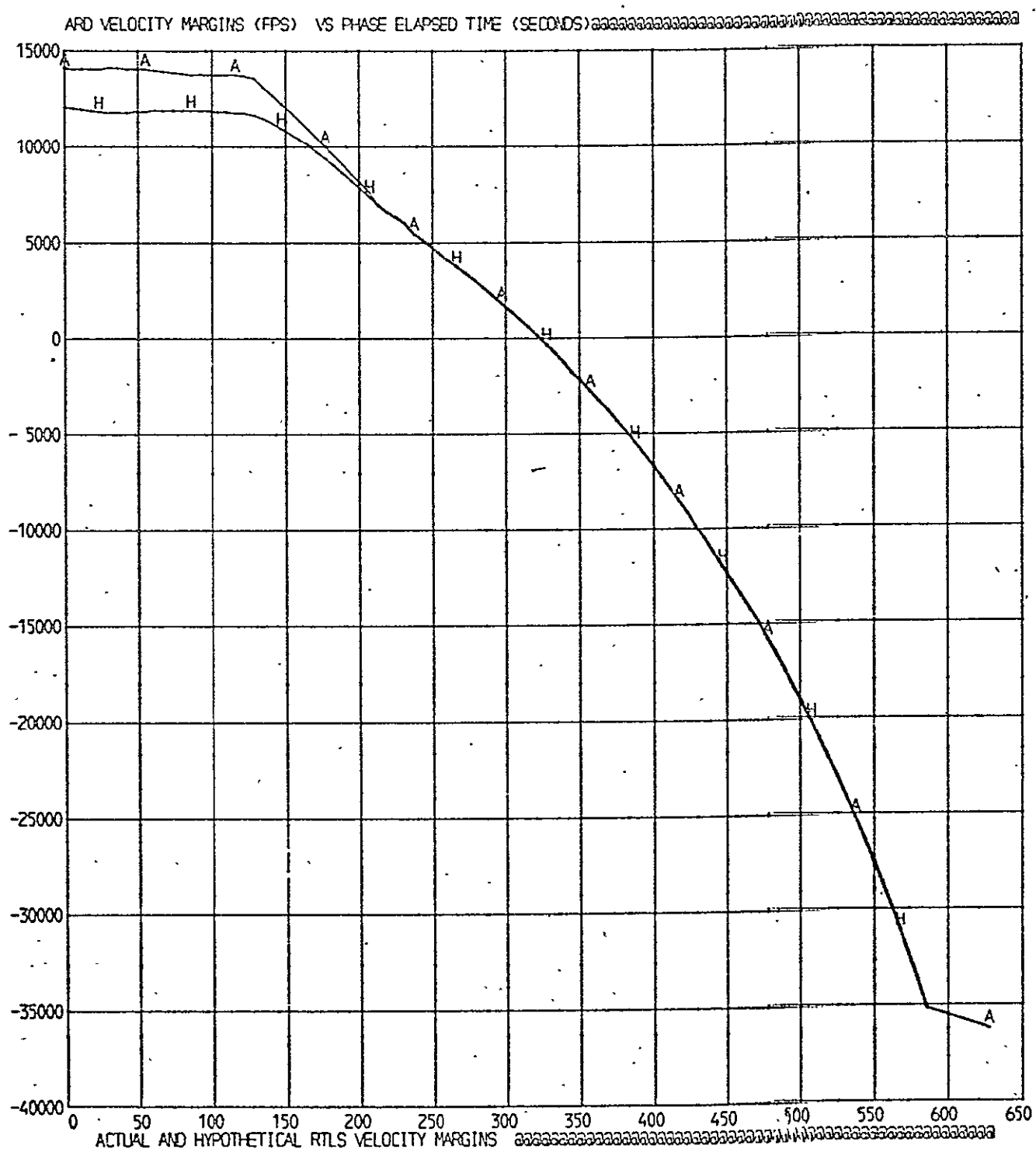


FIGURE 4.2: AOA-Aborted Mean-Wind OFT-1 - ARD RTLS Margin Histories

ABORT REGION DETERMINATOR

PET 213.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE I HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMAND	L	C	R	ABORT SEL	L	C	R
TLM	.00	.00	.00	NOM	.00	.00	.00
ARD	.00	1.09	1.09		.00	1.09	1.09

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM	-585.05	.00	-585.05	NOM	-585.56	.00	-585.56
RTLS	7012.69		7012.69	RTLS	7012.68		7012.68
AOA	-7.32	.00	-7.32	AOA	-7.32	.00	-7.32
ATO	-269.62	.00	-269.62	ATO	-269.62	.00	-269.62

EVENT TLM ARD			RTLS EVENT PREDICTION		
TCO	.00	424.3	DELO DIS	.00	TMICO
MECO	.00	37.29	TIME TO TURN	.00	RMECO
THEO	.00	213.0	PET TURN	.00	VMECO
VMEQ	.00	5737.	TIME END TURN	.00	GMECO

PRPLT	CMS	RCS	CURRENT WT	DELTH PITCH
LES	17584.	3797.	VEH1232677.I	MECO-IS
DELV	145.		ETP 937872.I	PITCHDOWN Z

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FIGURE 4.3: AOA-Aborted OFT-I ARD Digital Displays

ABORT REGION DETERMINATOR

PET 237.0 SELECTED SOURCE TLM GMT L/045000.0

ACTUAL MODE

HYPOTHETICAL MODE

THROTTLES				THROTTLES			
COMMAND	L	C	R	ABORT SEL	L	C	R
TLM	.00	.00	.00	AOA	.00	.00	.00
ARD	.00	1.09	1.09		.00	1.09	1.09

VEL MARGINS				VEL MARGINS			
REGION	MPROP	XOMS	SUM	REGION	MPROP	XOMS	SUM
NOM				NOM			
RTLS				RTLS			
AOA	3.96	.00	3.96	AOA	3.96	.00	3.96
ATO				ATC			

EVENT			RTLS EVENT PREDICTION		
TLM	ARD		TLM	ARD	
TEO	.0	305.1	TEO	.0	305.1
MECO	.30	632.13	MECO	.30	632.13
TMFO	.0	213.0	TMFO	.0	213.0
VMEO	.0	5737.	VMEO	.0	5737.

PRPLT	OMS	RCS	CURRENT WT	DELTHT PITCH
LBS	17584.	3797.	VEH1178661.1	MECC-IS
DELV	151.		ETP 683856.1	PITCHDOWN Z

FIGURE 4.3 CONTINUED

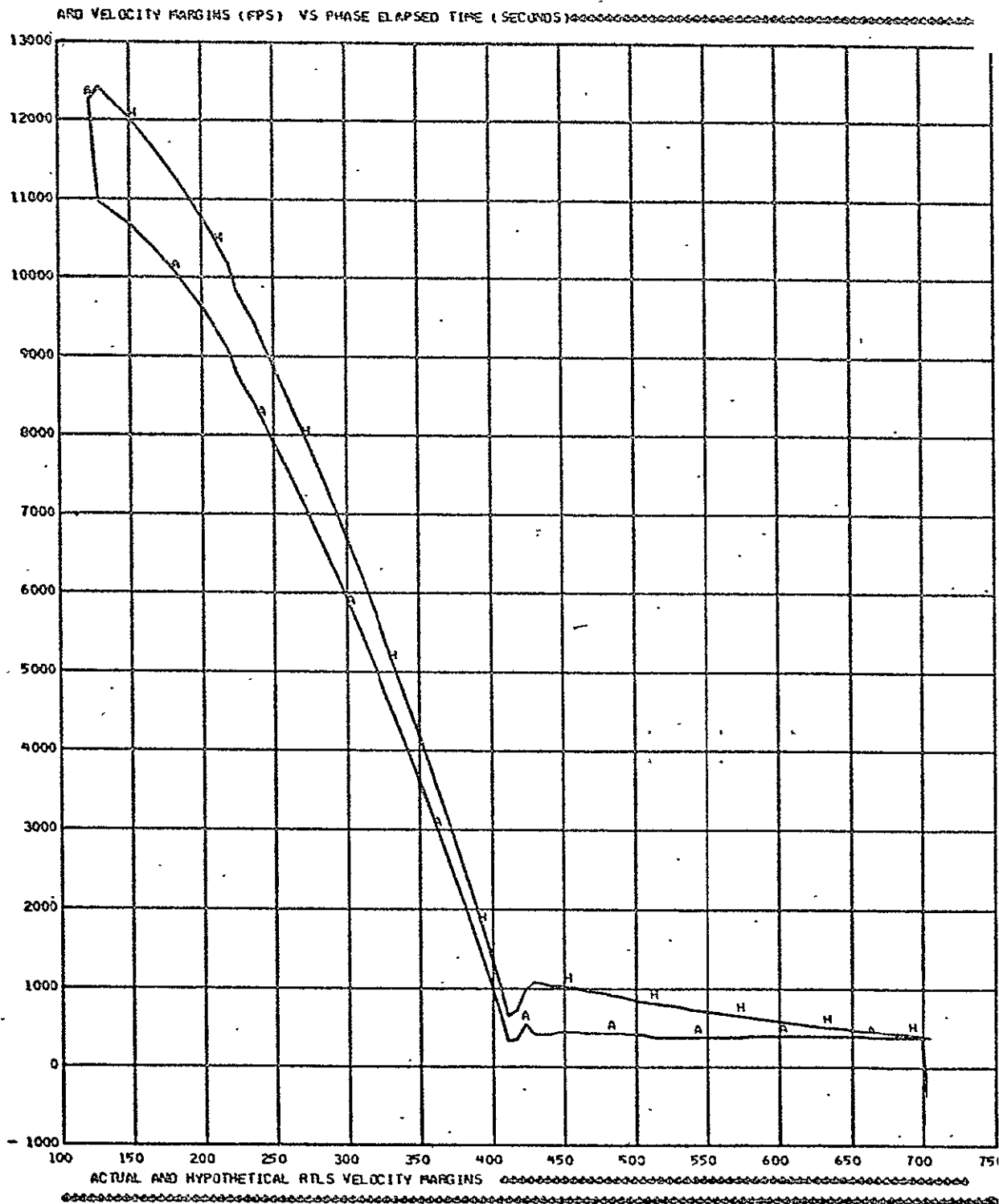


FIGURE 5.1: RTLS-Aborted Mean-Wind OFT-1 - ARD
RTLS Margin Histories

ABORT REGION DETERMINATOR

PET 122.7 SELECTED SOURCE TLM GMT L7045000.0

ACTUAL MODE

I HYPOTHETICAL MODE

COMMANDED THROTTLES

AEORT
SEL

THROTTLES

L C R
TLM .00 .00 .00
ARD .00 1.09 1.09

L C R
HYPOTHETICAL .00 1.09 1.09

REGION VEL MARGINS
MPROP XOMS SUM

REGION VEL MARGINS
MPROP XOMS SUM

NOM -2664.92 .00 .00

NOM -2664.92 .00 .00

RTLS12204.70 12204.70

RTLS12204.70 12204.70

AOA -1956.91 .00 .00

AOA -1956.91 .00 .00

ATO -2277.22 .00 .00

ATO -2277.22 .00 .00

EVENT TLM ARD

RTLS EVENT PREDICTION

TGO .0 58.0
MECO .00 180.68
TME0 .0 .0
VME0 0. 0.

DELO DIAS .0 TMECO .0
TIME TO TURN .00 RMECO .0
PET TURN .00 VMECO .0
TIME END TURN .00 GMECO .0

PRPLT OMS RCS CURRENT WT
LES 17584. 3797. VEH1574710.I
DELV 113. ETP1279905.I

DELTH PITCH .0
MECO-IS .0
PITCHDOWN 2 .0

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FIGURE 5.2: RTLS-Aborted OFT-1 ARD Digital Displays

ABORT REGION DETERMINATOR

PET 423.0 SELECTED SOURCE TLM GMT L7045000.0

----- ACTUAL MODE I HYPOTHETICAL MODE -----

THROTTLES				I	THROTTLES			
COMMANDED	.0			I				
L	C	R		I				
TLM	.00	1.09	1.09	I	HYPOTHETICAL	.00	1.09	1.09
ARD				I				

VEL MARGINS				I	VEL MARGINS			
REGION	MPROP	XOMS	SUM	I	REGION	MPROP	XOMS	SUM

NOM	[REDACTED]	[REDACTED]	[REDACTED]	I	NOM	[REDACTED]	[REDACTED]	[REDACTED]
RTLS	385.17		385.17	I	RTLS	831.74		831.74

AOA	[REDACTED]	[REDACTED]	[REDACTED]	I	AOA	[REDACTED]	[REDACTED]	[REDACTED]
ATO	[REDACTED]	[REDACTED]	[REDACTED]	I	ATO	[REDACTED]	[REDACTED]	[REDACTED]

----- EVENT TLM ARD I RTLS EVENT PREDICTION -----

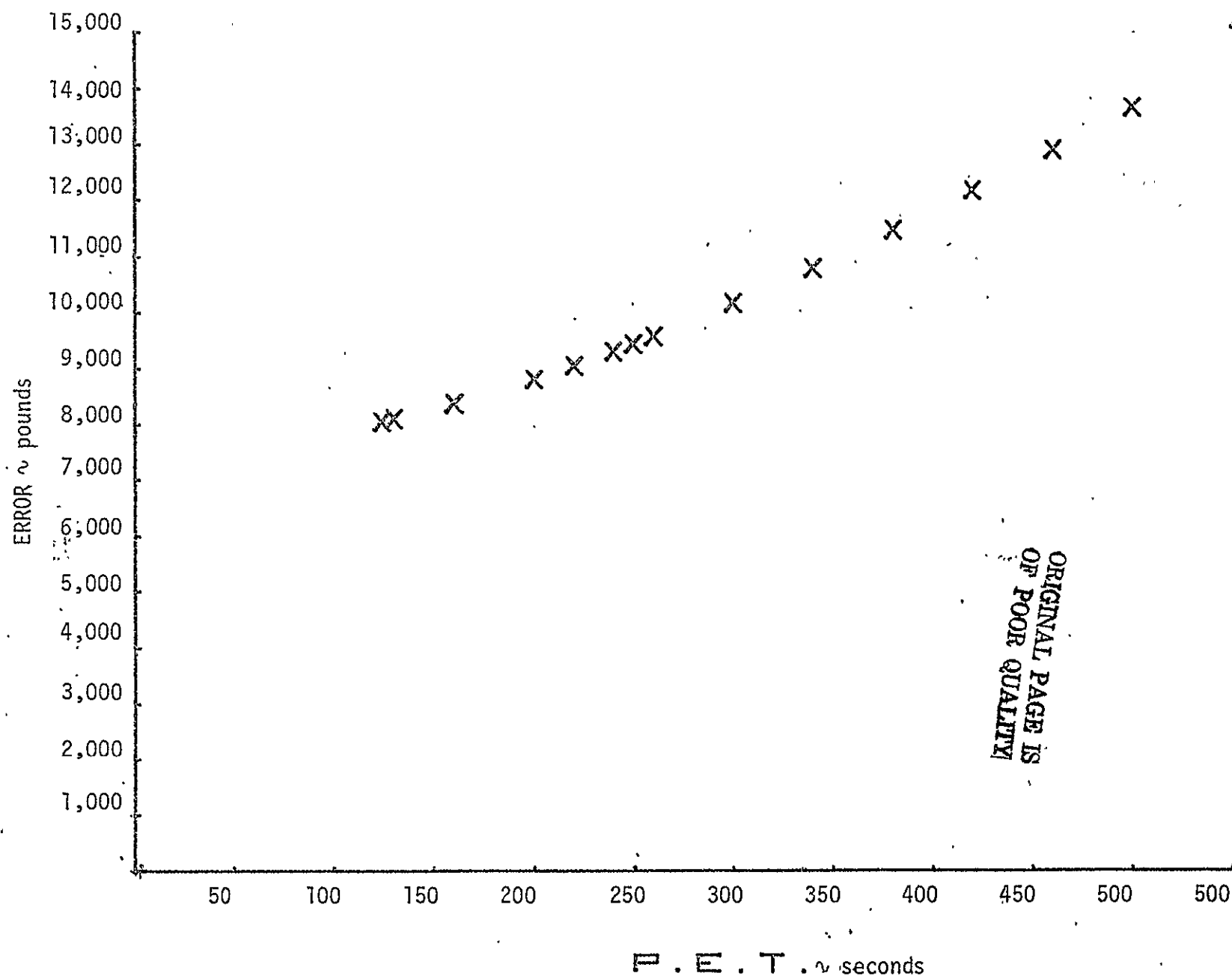
TGO	.0	*****	I	DELO DISS	.0	IMECO	.0
MECO	.00	*****	I	TIME TO TURN	.00	RMECO	.0
TME0	.0	.0	I	PET TURN	.00	VMECO	.0
VME0	.0	.0	I	TIME END TURN	.00	GMECO	.0

PRPLT	OMS	PCS	CURRENT WT	I	DELHT PITCH	.0
LBS	6320.	1053.	VEH 884753.I		MECO-IS	.0
DELV	72.	[REDACTED]	ETP 604006.I		PITCHDOWN Z	.0

FIGURE 5.3 CONTINUED

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FIGURE 6.1: Worst-Case Special MPS Processor Errors



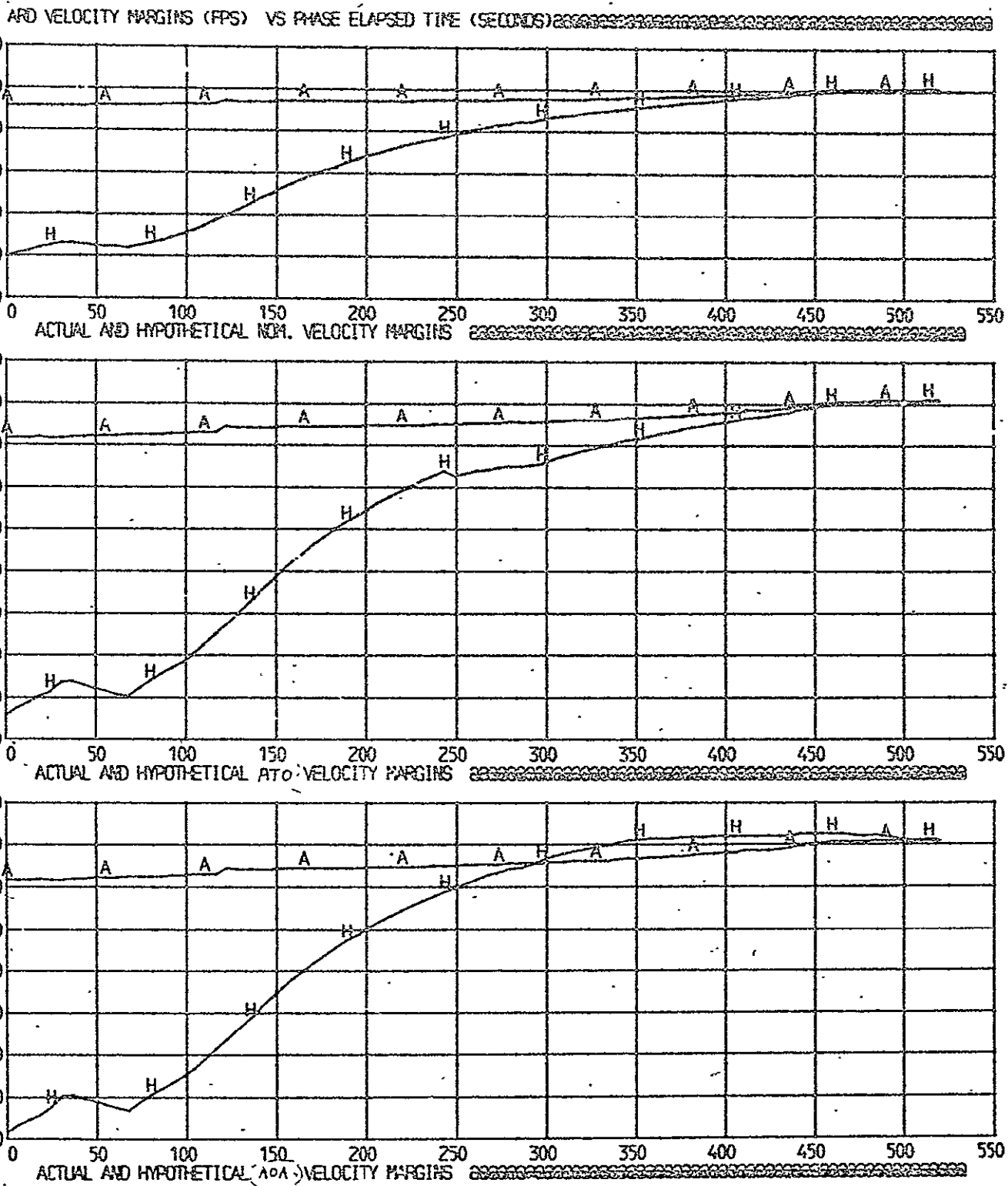


FIGURE 6.2: No-Wind OFT-1 ARD Downrange Margin
Histories for Worst-Case Special MPS
Processor Weight Errors

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ARD VELOCITY MARGINS (FPS) VS PHASE ELAPSED TIME (SECONDS)

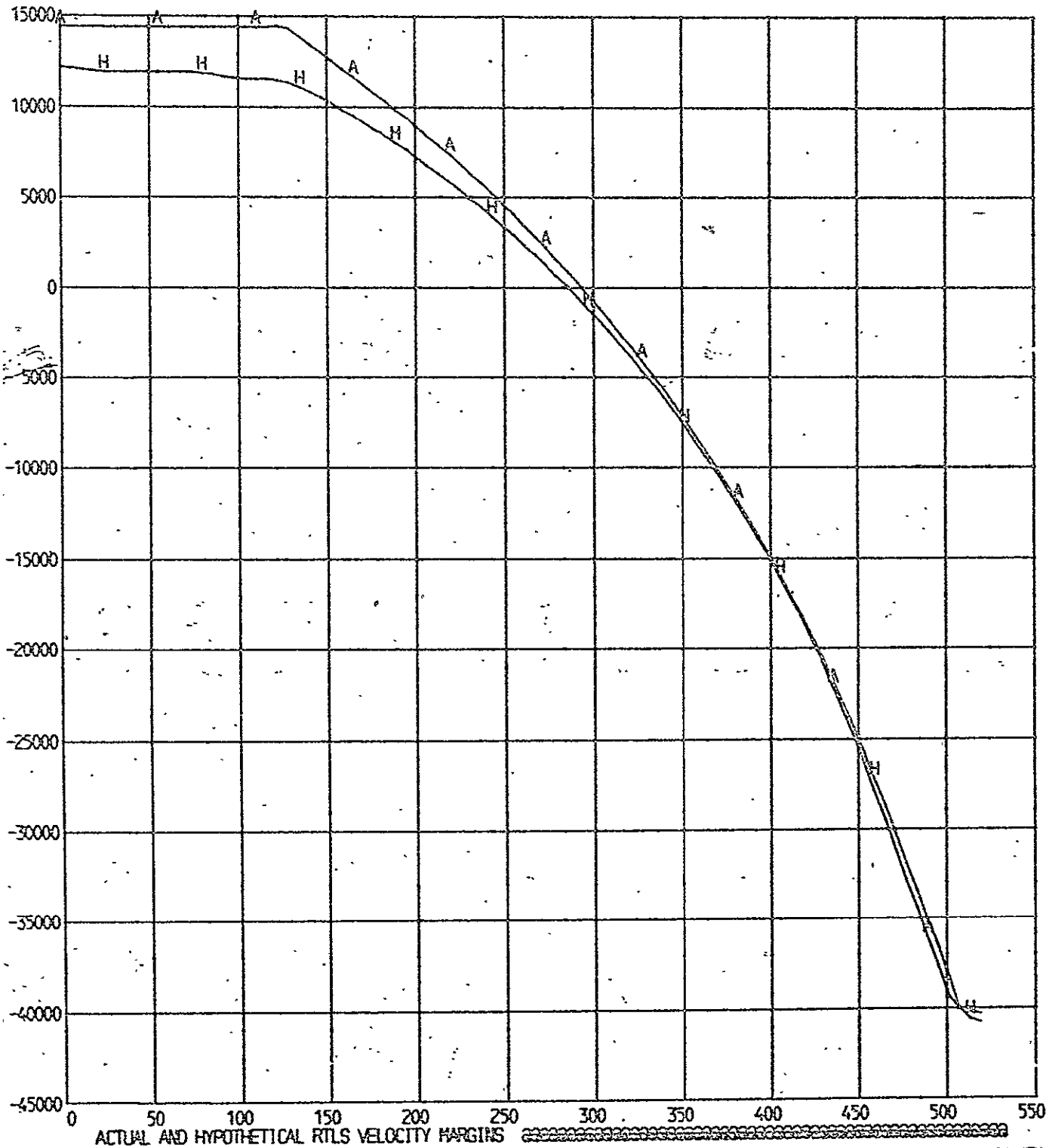


FIGURE 6.3: No-Wind OFT-1 ARD RTLS Margin History
For Worst-Case Special MPS Processor
Weight Errors

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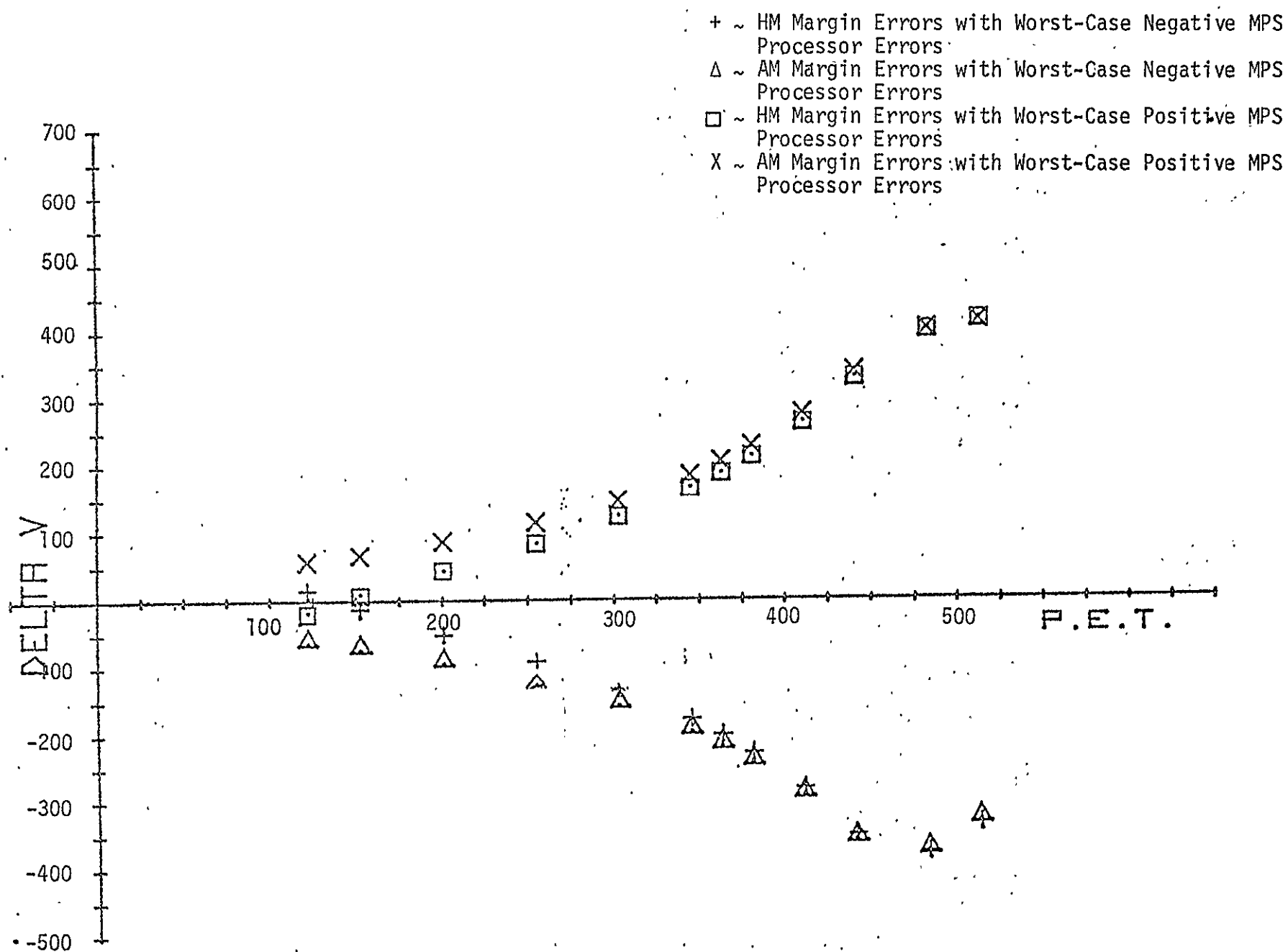


FIGURE (6.4): ARD Sensitivity To Worst-Case Special MPS Processor Errors

FIGURE 6.5: Worst-Case Special MPS Processor Errors Using Sensed Acceleration Algorithm

